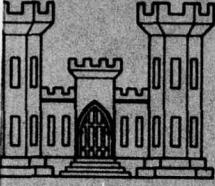


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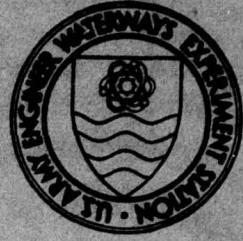


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# DREDGED MATERIAL RESEARCH PROGRAM

(12)



TECHNICAL REPORT D-77-20

## AQUATIC DISPOSAL FIELD INVESTIGATIONS GALVESTON, TEXAS, OFFSHORE DISPOSAL SITE

### APPENDIX B: INVESTIGATION OF WATER-QUALITY PARAMETERS AND PHYSICOCHEMICAL PARAMETERS

by

G. Fred Lee, Pinaki Bandyopadhyay, Jeannie Butler  
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Center for Environmental Studies  
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December 1977  
Final Report

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Monitored by Environmental Effects Laboratory  
U. S. Army Engineer Waterways Experiment Station  
P. O. Box 631, Vicksburg, Miss. 39180

**AQUATIC DISPOSAL FIELD INVESTIGATIONS,  
GALVESTON, TEXAS, OFFSHORE DISPOSAL SITE**

**Appendix A: Investigation of the Hydraulic Regime and Physical Nature of  
Sedimentation**

**Appendix B: Investigation of Water-Quality Parameters and Physico-  
chemical Parameters**

**Appendix C: Investigation of the Effects of Dredging and Dredged Material  
Disposal on Offshore Biota**

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DEPARTMENT OF THE ARMY  
WATERWAYS EXPERIMENT STATION, CORPS OF ENGINEERS  
P. O. BOX 631  
VICKSBURG, MISSISSIPPI 39180

IN REPLY REFER TO: WESYV

31 December 1977

SUBJECT: Transmittal of Technical Report D-77-20 (Appendix B)

TO: All Report Recipients

1. The technical report transmitted herewith represents the results of one of several research efforts (work units) undertaken as part of Task 1A, Aquatic Disposal Field Investigations, of the Corps of Engineers' Dredged Material Research Program. Task 1A is a part of the Environmental Impacts and Criteria Development Project (EICDP), which has a general objective determination of the magnitude and extent of effects of disposal sites on organisms and the quality of surrounding water, and the rate, diversity, and extent such sites are recolonized by benthic flora and fauna. The study reported on herein was an integral part of a series of research contracts jointly developed to achieve the EICDP general objective at the Galveston, Texas, Disposal Site, one of five sites located in several geographical regions of the United States. Consequently, this report presents results and interpretations of but one of several closely interrelated efforts and should be used only in conjunction with and consideration of the other related reports for this site.
2. This report, Appendix B: Investigation of Water-Quality Parameters and Physicochemical Parameters, is one of three contractor-prepared appendices published relative to the Waterways Experiment Station Technical Report D-77-20 entitled: Aquatic Disposal Field Investigations, Galveston, Texas, Offshore Disposal Site. The titles of all appendices of this series are listed on the inside front cover of this report. The main report will provide additional results, interpretations, and conclusions not found in the individual contractor-prepared reports and provide a comprehensive summary and synthesis overview of the entire project.
3. The purpose of this study, conducted as Work Unit 1A09C, was to determine the chemical impact of dredged material disposal upon the sediments and water column at the disposal site. The report includes a discussion of the nature of observed changes (or lack thereof) in a number of chemical and physical variables. The assessment data were

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obtained from sediment samples taken with a bottom grab and from water column information from remote sensing devices and samples taken with pumping apparatus.

4. It was concluded that few chemical and physical changes took place as a consequence of disposal. Those which did occur were generally of small magnitude or were within the natural variation observed in reference areas.

5. The results of this study will be of considerable importance in estimating the chemical impact that may be expected from the open-water disposal of similar dredged material under comparable conditions. The author suggests that a priori decisions relative to unconfined disposal are often invalid and that existing criteria for such disposal are in need of revision and/or modification.

JOHN J. CANNON

Colonel, Corps of Engineers  
Commander and Director

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) A study has been conducted on the environmental impact of the chemical contaminants present in dredged sediments which were dumped at a site in the Gulf of Mexico approximately five miles offshore of Galveston, Texas. Sediments from the Galveston Bay Entrance Channel and the Texas City Channel Turning Basin were dredged with a hopper dredge and dumped at the offshore disposal site. A series of pre-disposal surveys was conducted to establish background data on the characteristics of the disposal site water column and sediments. Nine dumps of dredged sediments were monitored, with sampling sites generally located 100 to 200 meters downcurrent from the dump sites. Postdisposal surveys were conducted to determine if the chemical contaminants present in the disposed sediments had residual effects on water quality. The heavy metals, copper, cadmium, mercury, lead, (Continued)		

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20. ABSTRACT (Continued).

nickel, zinc, chromium, iron, manganese, and arsenic; aquatic plant nutrients, such as nitrogen and phosphorus compounds; toxicants; and other parameters, such as oxygen demand and sulfide, were monitored before, during and after disposal.

Each disposal operation resulted in a turbid plume containing a small amount of finely divided dredged sediment which moved from the disposal site with the current. This turbid plume was rapidly dissipated or transported from the sampling area. No residual effects were found a few hours following cessation of disposal. There was release of some contaminants, such as ammonium and manganese, associated with the turbid plume. The contaminant concentrations found were generally below those known to cause water-quality problems considering the time and concentration relationships existing for organisms inhabiting the water column at or near the disposal site. Most contaminants studied were not released with passage of the turbid plume.

Sediment studies showed that disposal of Galveston Bay Entrance Channel sediments did not significantly change the overall chemical characteristics of the sediments. The chemical contaminants present in these dredged sediments were not present in sufficient concentrations and forms to be a major factor in determining the numbers and types of benthic organisms present in the disposal site area. Further studies need to be conducted to determine the ultimate duration and fate of the turbid plume associated with the dredged material disposal operation and whether the concentrations of contaminants present in the dredged sediments could bioconcentrate in organisms of the area.

Overall, the study has shown that open-water disposal of sediments dredged by hopper dredge from the Texas City Channel Turning Basin and Galveston Bay Entrance Channel would not be expected to have a significant adverse effect on water quality in the Galveston Bay Entrance Channel offshore disposal site water column.

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## SUMMARY

One of the major environmental quality problems facing the Corps of Engineers, the dredging industry, and those responsible for maintenance and operation of harbors and waterways in the U. S. is that of determining the best overall method for dredged material disposal. Because chemical contaminants in many dredged sediments have exceeded the arbitrary criteria developed by some water pollution control regulatory agencies, alternate methods of dredged material disposal have been adopted. This has, in many instances, increased the cost of disposal. This situation led to creation of the Corps of Engineer Dredged Material Research Program (DMRP), which was specifically designed to provide information to be used in determining the best overall method of disposal of dredged sediments.

A phase of the DMRP which was particularly important to the overall objectives of the program was comprised of field studies designed to evaluate the actual environmental impact of dredged material disposal at selected sites in the U. S. One of these sites was in the Gulf of Mexico, approximately five miles off of Galveston, Texas. The DMRP project at Galveston consisted of three major components: studies on the currents, geology and fate of dredged sediments deposited at the Galveston site; water-quality studies on the water column and sediments before, during and after dredged material disposal operations; and studies on the effect of dredged material disposal on the numbers and types of aquatic organisms present in the disposal area. This report presents the results of the water-quality studies conducted in the Galveston Bay Entrance Channel disposal area.

The overall approach involved collecting initial samples of water and sediment from the dredging and disposal

sites between April and August 1975 before major disposal operations commenced. These samples were analyzed for the following heavy metals: copper, cadmium, zinc, lead, nickel, mercury, chromium, arsenic, iron and manganese. Additional analyses were made for nutrient compounds with particular emphasis on phosphorus compounds and ammonium. Oxygen demand, turbidity, sulfide and other parameters or compounds thought to be indicative of the potential pollutional characteristics of the water and sediment samples or helpful in interpreting the data were also monitored.

In a companion study reported elsewhere, samples were collected and analyzed for various organic compounds, including chlorinated hydrocarbon pesticides and PCB's. That study also presents the detailed examination of the relationship between the results of the elutriate test on dredged sediments and what was actually released according to measurements taken aboard the hopper dredge and in the disposal site water column. The results of these studies will be included in a report to the U. S. Army Corps of Engineers Waterways Experiment Station in 1977.

In this study nine disposal operations were followed in detail. Seven of these each involved approximately 1,000 cubic meters of Galveston Bay Entrance Channel sediments hydraulically dredged by the hopper dredge, McFarland. In addition, two dumps of sediments dredged from Texas City Channel and Turning Basin were monitored. The Galveston Bay Entrance Channel sediments are generally considered by the US EPA to be relatively uncontaminated while those of the Texas City Channel Turning Basin are generally considered highly contaminated and usually require special methods of disposal.

The monitoring of each disposal operation consisted of positioning a sampling ship 100 to 200 meters

downcurrent from the proposed disposal site. The hopper dredge dumped the sediments at the specific location, and the water column was sampled at surface, mid-depth and near bottom in order to detect changes in the characteristics of the water column resulting from passage of the turbid plume. This plume consisted of the small amounts of suspended matter which had not immediately settled to the bottom. The water column in this area varied in depth from 10 to 17 meters.

Three dumping periods were monitored: one in late August, another in mid-September, and the third in mid-October, 1975. After disposal operations had ceased, additional water column and sediment samples were taken on several occasions to determine long-term effects of the disposal operations on water quality.

It was found that water quality in the disposal site water column is determined by the relative mixture of three distinct water sources. These are the uncontaminated open waters of the Gulf of Mexico, the slightly contaminated nearshore Gulf waters and the relatively highly contaminated Galveston Bay waters which receive waste input from municipal and industrial complexes on the Houston Ship Channel and Galveston Bay. The relative mixing of these three water masses is dependent on the wind and tides and the general circulation patterns of the Gulf of Mexico.

Elutriate tests conducted on sediments scheduled for dredging indicated that manganese and ammonium could be released in quantities which, if persistent, could have a significant adverse effect on water quality at the disposal site. Monitoring of actual dumps did show that the concentrations of manganese and ammonium in the water column were slightly elevated during the passage of the turbid plume. However, the magnitude of release in the turbid plume and

the expected exposure time were not sufficient to adversely affect water column organisms.

All other compounds and parameters tested showed either no release or insufficient release to have any adverse effect on water quality at the disposal site. Dissolved oxygen (D.O.) depletion, which is frequently of concern to pollution control agencies, generally showed a 1 to 3 mg/l reduction for a few minutes during the passage of the turbid plume. In some instances, the bottom waters adjacent to the disposal site showed D.O. depletion of several mg/l for several hours; however, within a few hours the D.O. returned to normal ambient conditions. Post-disposal monitoring showed that the disposal operation had no residual effect on water quality at the disposal site and adjacent water columns.

Sediment studies before and after disposal showed that the chemical contaminants in the Galveston Bay Entrance Channel dredged sediments had no readily discernible effect on the chemical characteristics of the disposal site sediments. No studies were done on the effect of the Texas City Channel and Turning Basin sediments on the disposal site sediment. It is expected, however, that the effects of these sediments would be short term due to the mixing and dispersion of sediments that occur at the disposal site. The rapid mixing of contaminated sediments with less contaminated sediments generally dilutes the contaminants to levels below critical concentrations for adverse effects on water quality. From these studies, it seems likely that any deleterious effects of dredged material disposal on aquatic organisms at the disposal site would be from physical rather than chemical causes.

From an overall point of view, the water-quality studies at the Galveston Bay Entrance Channel disposal site

led to the conclusion that the disposal of hopper dredged Galveston Bay Entrance Channel sediments may take place at that site without significant adverse effect on water quality near the disposal site. It is conceivable that in some cases environmental considerations have led to adoption of disposal techniques which are not only more expensive than previously used open-water disposal methods, but also more detrimental to the ecosystem. A series of studies should be conducted on confined or onland disposal practices in the Texas Gulf Coast region to enable comparison of the environmental impact of these methods with the open-water disposal studied in this investigation. Further studies should be conducted at the Galveston Bay Entrance Channel Disposal Site to ascertain whether potentially significant bioconcentration of contaminants present in the dredged sediments is occurring in the organisms of the area. Additional studies are needed to determine the long-term fate of the chemical contaminants present in the turbid plume of dredged sediment arising from disposal operations.

In the past half dozen years, there has been a marked increase in the cost of dredging and disposal because dredgers are forced to seek alternate methods of disposal when the chemical contaminants in the sediments exceed arbitrary bulk chemical criteria. It is recommended that use of such criteria as a basis for judging the potential environmental significance of dredged material disposal on receiving water quality be immediately terminated. The region should adopt the approach of critically evaluating the actual environmental impact of alternate methods of disposal. Based on this

evaluation, the disposal method which provides the best overall relationship between the cost of dredged material disposal and ecological damage should be adopted.

## PREFACE

The work described in this report was performed under Contract No. DACW64-75-C-0071, titled "An Investigation of Water Quality Parameters and Physicochemical Parameters at the Offshore Disposal Site, Galveston, Texas" dated March 10, 1975, between the Galveston District, U. S. Army Corps of Engineers, Galveston, Texas; the Environmental Effects Laboratory, U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Mississippi; and the Center for Environmental Studies, University of Texas at Dallas (UTD), Richardson, Texas. The research was sponsored by the Office, Chief of Engineers (DAEN-CWP-M) under the civil works research program, "Dredged Material Research Program."

This report presents the results of a field study devoted to evaluation of the environmental impact of open water disposal of dredged material. Particular emphasis has been devoted to evaluating the release of chemical contaminants from the dredged sediments in the disposal site water column. Sediments were dredged from the Galveston Bay Entrance Channel and the Texas City Channel Turning Basin by the hopper dredge McFarland and disposed of at the dredged material disposal area south of the Galveston Bay Entrance Channel. This study was conducted during the period March 1975 through January 1976.

Principal investigator and prime author of the report was Dr. G. Fred Lee, Professor and Director, Center for Environmental Studies, UTD. Dr. Lee was assisted by the following: Pinaki Bandyopadhyay, Jeannie Butler, Rusty Nicar, Farida Saleh, Dr. Marvin Piwoni and Dr. Cameron McDonald. Dr. McDonald is a post-doctoral fellow in the Center for Environmental Studies at UTD. Dr. Piwoni is an

assistant professor in the Environmental Sciences Program at UTD. All of the others were, during the time of the study, graduate students in the Environmental Sciences Program at UTD. Special recognition is given the assistance of Drs. T. Waller and G. Lanza, both associate professors in the Environmental Sciences Program at UTD for their help in sample collection. Sample collection and analysis was accomplished with the assistance of many individuals. Particularly noteworthy was the assistance of C. Frederick, D. Morgan, L. Shendock, T. Palit, B. Siegal, F. Wang, and B. Werner.

The editorial assistance of L. Strauss and J. Hale and the secretarial assistance of S. Elder, H. Head, M. Jaye, L. Lawhorn, P. Lee, L. Millender, J. Raiburn, M. Thomas and P. Wernsing is greatly appreciated. We also wish to acknowledge the assistance given this study by D. Canham and Glenda Max, UTD Center for Advanced Studies, and others on the UTD staff.

Several members of the Texas A&M University staff assisted in this study. Special recognition is given to Drs. D. Harper, A. Bouma, G. Huebner, and S. Ray. Another group that greatly aided this study was the Galveston District of the Corps of Engineers. The assistance of COL D. S. McCoy, District Engineer, MAJ M. L. Howell, Jr., D. Dunn, and CPT Paul R. Greenwood and the crew of the dredge McFarland contributed significantly to the success of this study. Several members of the U. S. Army Corps of Engineers Waterways Experiment Station (WES), staff greatly aided this study. Especially significant contributions were made by R. Engler, D. Mathis, S. Cobb and B. Holliday.

We wish to acknowledge the assistance or members of the US EPA Region VI and the Texas Water Quality Board staff for giving permission to conduct the Texas City Channel Turning Basin studies. Special recognition is

given to J. Flynn of Hydrolab, Inc., Austin, Texas, for his assistance during the course of this study.

We wish to acknowledge the assistance of COL R. W. Martindale and the staff of the Marine Biomedical Institute of the University of Texas Medical Branch-Galveston.

This contract was monitored by David B. Mathis under the supervision of Dr. Robert M. Engler. The Contracting Officer was COL D. S. McCoy.

Directors of WES during the conduct of this study were COL G. H. Hilt, CE, and COL J. L. Cannon, CE. Technical Director was Mr. F. R. Brown.

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CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI)  
UNITS OF MEASUREMENT

The U. S. customary units of measurement used in this report can be converted to metric units as follows:

Multiply	By	To Obtain
inches	2.54	centimeters
feet	0.3048	meters
miles (U. S. statute)	1.609344	kilometers
cubic yards	0.7645549	cubic meters
tons (short)	907.1847	kilograms
pounds (mass) per acre	0.000112	kilograms per square meter
miles (U. S. statute) per hour	1.609344	kilometers per hour
knots (international)	0.5144444	meters per second
horsepower	745.6999	watts
Fahrenheit degrees	0.555	Celsius degrees or Kelvins*

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\* To obtain Fahrenheit (F) temperature readings from Celsius (C) readings, use the following formula:  $F = 9/5(C) + 32$ .  
To obtain Fahrenheit readings from Kelvins (K), use:  
 $F = 9/5(K - 273.15) + 32$ .

AQUATIC DISPOSAL FIELD INVESTIGATIONS, GALVESTON,  
TEXAS, OFFSHORE DISPOSAL SITE

APPENDIX B: INVESTIGATION OF WATER-QUALITY PARAMETERS  
AND PHYSICOCHEMICAL PARAMETERS

PART I: INTRODUCTION

The U. S. Army Corps of Engineers (CE) has the statutory responsibility for maintenance of the desired navigable depth for U. S. waterways. Until the late 1960's the CE District Engineers generally permitted disposal of dredged sediments by the overall least expensive method, usually in nearby deeper water. Ecological considerations involving dredged material disposal were primarily directed toward avoiding disposal in the areas of known ecological sensitivity, such as shellfish beds and spawning areas.

In the early 1970's these ecological considerations were broadened to include the potential detrimental effects of the chemical contaminants associated with dredged sediments. At that time, the District Engineers found that sediments which had been disposed of previously in nearby water courses were now classified as polluted and alternate methods of disposal had to be developed. With a few exceptions, the alternate methods of disposal resulted in increases in costs of dredging operations.

Classification of sediments as polluted was based on bulk chemical criteria developed by the U. S. Environmental Protection Agency (US EPA) and its predecessor organizations. Review of the potential significance of chemical contaminants associated with dredged sediments in light of the information available when these bulk chemical criteria were adopted leads one to conclude

that their use may not be technically valid. They are likely to be over-restrictive and may result in greater harm due to the environmental impact of alternate disposal methods.

Examination of the potential environmental impact of chemical contaminants associated with dredged sediments shows that there are two potential areas of concern. One is over the disposal site water column, where there might be short-term effects from the release of chemical contaminants. Released in sufficient concentrations, these contaminants could be toxic to desirable aquatic organisms. The second is over the long-term effects of the chemical contaminants in the redeposited sediments on benthic and epibenthic organisms. These two areas of concern are distinctly different in terms of the type of organisms affected, the time frame over which potential effects are to be considered, the methods and approaches developed to study the two areas and the impact on the overall beneficial uses of the aquatic ecosystem involved. In addition to effects on aquatic organisms, it is possible for dredged material disposal in open waters to have detrimental effects on water quality associated with domestic water supplies. These are generally short-term effects associated with the water column, occurring during or shortly after disposal.

In the early 1970's, Congress appropriated funds for the Army Corps of Engineers to initiate a \$30 million, five-year research program devoted to evaluation of the potential environmental impact of dredged material disposal. One of the primary components of the Dredged Material Research Program (DMRP) is an evaluation of the potential environmental impact of dredged material disposal on water quality, with particular emphasis on the significance of chemical contaminants present in dredged sediments.

The DMRP utilized a combination of laboratory and field studies to make this evaluation. The DMRP management team chose four field sites for intensive studies. One of the sites was located near the Galveston Bay Entrance Channel in the Gulf of Mexico. The Galveston study represented a joint effort between the Corps of Engineers Waterways Experiment Station (WES) Dredged Material Research Program (DMRP), the Galveston District of the Corps of Engineers, Texas A&M University Moody College and College Station campuses and the University of Texas at Dallas (UTD) Center for Environmental Studies.

The study at this site involved a three-component approach in which the long-term effects of dredged disposal were evaluated. The benthic organisms at the Galveston Bay Entrance Channel (GBEC) disposal site were to be examined by D. Harper at Texas A&M Moody College in Galveston, Texas. A. Bouma of Texas A&M-College Station was responsible for defining the overall hydraulic regime of the Galveston site and the fate of the sediments disposed of in the area. The third component of the study was conducted at UTD. This part was concerned with the short-term effects of disposal on water quality in the water column at the disposal site during and shortly after disposal. It was also concerned with the physical and chemical characteristics of the sediments. This report presents the results of the third part of the study.

The basic approach used in the UTD phase of the Galveston studies was to conduct pre-disposal studies in order to establish the baseline characteristics of the dredging and disposal areas. Primary emphasis was placed on measuring the concentrations of contaminants released to the water column during the disposal operations. In

addition, some post-disposal studies were conducted to determine if the disposal site water column showed any residual effects arising from the chemical contaminants present in the dredged sediments. Also, the physical and chemical characteristics of the sediments in the disposal area (both before and after disposal) were characterized to a limited extent.

The study plan called for collection of pre-disposal data several months prior to any disposal at the site. On May 7-13, a limited disposal operation was initiated but had to be terminated because of mechanical problems with the hopper dredge McFarland. The McFarland became operative again in late August 1975 and began to dredge the Galveston Bay Entrance Channel during the last week in August. A total of nine dredged material disposals were monitored. Seven of these utilized sediments dredged by the hopper dredge McFarland from GBEC. Two disposal operations using material dredged from the Texas City Channel Turning Basin (TCCTB) were monitored in October 1975.

Based on bulk chemical criteria, the TCCTB sediments are generally classified as highly contaminated compared to GBEC sediments. This study plan enabled a comparison to be made between the environmental impact of disposal of "relatively uncontaminated" vs. "highly contaminated" sediments. Thus, an evaluation of the reliability of bulk sediment criteria for prediction of environmental impact during open-water disposal could be made. Post-disposal water column samples were taken to determine if there was sufficient release of contaminants from the dredged sediments to alter water quality at the disposal site.

In association with the biological studies on benthic organisms, sediment samples were collected prior

to and after the disposal operations. These sediments were analyzed for various physical and chemical characteristics for the purpose of examining any relationship between changes in numbers and types of benthic organisms and the sediment characteristics.

A companion study devoted to evaluating the reliability of the elutriate test, supported by WES, was conducted parallel to this study. This study involved taking samples of sediment from the proposed dredging sites (TCCTB and GBEC) and measuring the amounts of contaminants released in the elutriate test. Measurements were made of the concentrations of contaminants actually released in the hopper of the dredge and in the water column at the disposal site. In addition to measurements of heavy metals and nutrients, the elutriate test studies included measurements of chlorinated hydrocarbon pesticides and PCB's. The results of the elutriate test studies will be presented in a report issued by WES.<sup>1</sup>

## PART II: LITERATURE REVIEW

The literature pertinent to this study may be divided into two categories. One is concerned with general background of the expected environmental problems and behavior of chemical contaminants associated with open-water disposal of dredged sediments. The other includes the literature devoted to previous studies in the Gulf of Mexico-Galveston Bay area, which might provide an additional data base to aid in interpreting the significance of the results obtained in this study. This part of the report presents a review of literature pertinent in both categories.

### General Relationships of Dredged Material Disposal and Water Quality

In 1974, Lee and Plumb<sup>2</sup> presented a comprehensive review of the literature relevant to the potential environmental impact of open-water disposal of contaminated sediments. This review was subsequently expanded by Lee *et al.*<sup>3</sup>. The reader is referred to both of these reviews for further information on many of the topic areas discussed below.

It was concluded in these reviews that very little work had been done on evaluating the water-quality problems associated with open-water disposal of sediments containing large amounts of chemical contaminants. Lee and Plumb<sup>2</sup> reviewed the information available on the factors influencing the release of contaminants from sediments and concluded that there were two distinct problem areas to be considered in connection with open-water disposal of dredged sediments. These problems included the potential for release of contaminants to the dredged material disposal site water column during the disposal operation. This situation is characterized as being short term in nature. The other problem area concerned potential long-term effects of the contaminants

in dredged sediments that are redeposited on the bottom at the disposal site. This effect primarily would be one of a long-term adverse impact on the numbers and types of benthic and epibenthic organisms inhabiting the sediments. There might be a beneficial impact of improving habitats for certain types of organisms. This problem area also covered bioaccumulation of chemical contaminants in aquatic organisms; such bioaccumulation could be adverse to other animals and man.

There is a lack of information on both problem areas in association with the actual disposal of dredged material. This led Lee and Plumb<sup>2</sup> and Lee et al.<sup>3</sup> to review them from the point of view of considering what is known about the release of contaminants to the water column upon suspension of sediments and the relationships between the concentrations of various types of contaminants present in sediments and benthic organisms living in them. They concluded that, from the expected environmental chemistry of various contaminants associated with sediments, there should be little or no release of contaminants at the disposal site water column once the water associated with the dredged sediment had become oxic. Under these conditions, the reduced iron normally present in natural water sediments would be oxidized to the ferric form. This would precipitate as a ferric hydroxide and scavenge from the water column many, if not all, of the contaminants released under the temporary anoxic conditions created by dredged material disposal.

While environmental quality problems at the disposal site water column were expected to be small in most instances, Lee and Plumb<sup>2</sup> recommended development of a leaching test which could be used to estimate release of contaminants from the sediments scheduled to be dredged. They examined the literature relevant to the factors that

could influence the behavior of various types of contaminants in a leaching test such as the elutriate test proposed by the US EPA and CE. They recommended that laboratory studies be conducted to evaluate these factors. In these studies, elutriate tests would be performed on sediments scheduled to be dredged to enable comparison of the results from the elutriate test to those obtained in actual dredged material disposal operations. This report presents a followup to the original recommendations of Lee and Plumb in this area.

From the available information, Lee and Plumb<sup>2</sup> discerned a potential for certain types of chemical contaminants in dredged sediments to have an adverse effect on the numbers and types of aquatic organisms. This adverse effect could be manifested in two ways: either directly on the organisms present in the sediments or indirectly on higher trophic level organisms through bioaccumulation of the contaminants. They concluded, however, that information available at that time was insufficient to determine whether this was a real problem in association with dredging and dredged material disposal.

One of the focal points of their review was on the technical validity of the bulk chemical criteria that had been developed by the US EPA and its predecessor organizations as a basis for determining the pollutional characteristics of dredged sediments. From previous studies and the expected environmental behavior of contaminants associated with dredged sediments, Lee and Plumb<sup>2</sup> concluded that the bulk chemical criteria in existence then (and to some extent, today) had little or no technical validity as a basis for determining whether the amount of contaminant present in a particular sediment would have an adverse effect either on water quality in the disposal site water column or on the benthic or higher trophic level organisms in the disposal site sediments.

Lee<sup>4</sup> recommended that the US EPA terminate the use of bulk chemical criteria as a basis for determining the pollutional tendencies of dredged sediments and that they adopt the elutriate test as a means of assessing the potential environmental impact of open-water disposal of dredged sediments to the disposal site water column.

The elutriate test, originally promulgated in Public Law (PL) 92-532 which was known as the "Ocean Dumping Act", involved mixing a known volume of water and sediment to be dredged, shaking for a 30-minute period, settling for one hour and determining the amounts of contaminants released to the water. Keeley and Engler<sup>5</sup> discussed the utilization of this test as a standard procedure for assessing the pollutional tendencies of dredged sediments. Lee et al.<sup>3</sup> studied the factors influencing the results of the elutriate test and concluded that the original version of this test promulgated in PL 92-532 was unreplicable and that for some sediments, the results were dependent on minor variations in test operating conditions. It was recommended that the elutriate test be modified to include the use of compressed air for mixing the test solution and that a 1-to-20 sediment-water mixture be used (rather than the 1-to-4 recommended in the original test). However, varying such test conditions as length of shaking time, settling time, and method of agitation (provided that a well-defined redox condition was developed) did not influence the test results.<sup>3</sup>

Only two compounds (ammonia and manganese) out of approximately 30 common chemical contaminants studied were released during the modified elutriate test for a variety of dredged sediments taken from various locations throughout the U. S.<sup>3</sup> Further, Lee et al.<sup>3,6</sup> found that the elutriates had only limited toxicity to various types of aquatic organisms, indicating that even though a sediment may be highly

contaminated with chemical contaminants, the majority of these are in a form which is not available to be released to the water column.

Lee et al.<sup>3,7</sup> recommended that further work be done on evaluating the factors influencing the results of the elutriate test and that studies were needed to compare the elutriate test results to actual field conditions. While it was not one of the primary objectives of these studies, such data have become available because of this study. They will be reported in a subsequent report by Lee et al.<sup>1</sup>

Previous Studies Pertinent to Water Quality,  
Galveston Bay Entrance Channel

Few studies have been conducted which provide background information useful to understanding the potential environmental impact of dredged material disposal in the disposal area adjacent to the Galveston Bay Entrance Channel. A review of selected references on this topic area is presented below.

Water Clarity

Water depths in Galveston Bay and the nearshore waters of the Gulf of Mexico are shallow. This results in the water of this area being normally turbid with Secchi depths in the order of approximately 1 m or less. This turbidity arises from wind and tide-induced currents which scour the sediment, suspending finely divided particles in the water. In addition, the intensive commercial ship traffic in the area and shrimp trawling further increase to an undetermined extent the turbidity of the waters in the study area.

Based on a study conducted in Galveston Bay, Masch and Espey<sup>8</sup> observed that the amount of sediment forced into suspension by dredging operations was at least an order of magnitude greater than that suspended by currents, winds, wave action and ship traffic. They also found

that the greatest sediment load was caused by density differences.

Masch and Espey<sup>8</sup> noted that density layers are formed when the material discharged is more than 80 percent (by weight) silt and clay, of which at least half is clay. The movement of these layers was controlled by gravity or tidal action (not local currents) until the concentration exceeded 175 grams per liter. At that concentration, the layer consolidated and settled to the bottom.

From their work in Galveston Bay, Masch and Espey<sup>8</sup> concluded that properly planned and controlled shell dredging could be carried out very close to live oyster reefs. However, they recommended routine monitoring of dredging and disposal activities to assess possible damage resulting from deposition of sediment at the oyster reefs. It should be noted that in Texas, dredging within 300 feet\* of a live oyster reef is prohibited.<sup>9</sup>

#### Dissolved Oxygen - Oxygen Demand

The Galveston Bay estuary system is the end point for the Trinity River drainage basin, San Jacinto River drainage basin and the Houston Ship Channel-Buffalo Bayou drainage basin. The sediment carried by these water bodies is deposited in the Galveston Bay system as the water moves to the Gulf of Mexico. Some of these particles are deposited in the channels, thereby causing a need for maintenance dredging. The type materials deposited in the channels can play a part in the oxygen demand of the sediment when dredged. The Bernard-Johnson report<sup>10</sup> stated that the total BOD<sub>5</sub> exerted by the streams in Harris County, Texas, which feed the Galveston Bay, was 130,600

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\* A table of factors for converting U. S. customary units of measurement to metric (SI) can be found on page 34.

lb/day. The industrial and municipal wastes averaged 40,100 and 98,000 lb/day  $BOD_5$ , respectively, for a total of 138,100 lb/day. Coupled with the benthic demand, the overall total  $BOD_5$  loading in the Galveston Bay system was 268,700 lb/day. Part of this BOD load is deposited in the sediments which are later dredged and disposed.

This report also stated, "Normally the bay with its diversity of enclosed environments is subject to a rather large  $BOD_5$  loading from runoff and natural productivity. Because of the large productivity of Galveston Bay, estimated at 53 pounds of carbon per acre per day, when the wind ceases to mix the bays, oxygen demand may exceed the availability of molecular oxygen and the content of oxygen may fall below the level considered to be healthy for the biota."<sup>10</sup>

The oxygen levels set forth in the US EPA Quality Criteria for Water<sup>11</sup> list a low of 4.0 mg/l as acceptable. The Texas Water Quality Board<sup>12</sup> reported the mean D.O. concentrations ranged from 6.0 to 9.5 mg/l over a six-year period in the Galveston Bay.

Reynolds et al.<sup>13</sup> investigated the oxygen demand of the Houston Ship Channel sediments during three conditions: quiescent, scoured and completely suspended. Under quiescent conditions the oxygen demand ranged from 0.12 g /hr-m<sup>2</sup> at Mile 0 to 0.22 g /hr-m<sup>2</sup> at Mile 20. They reported insignificant changes from quiescent to scoured, 0.084 g /hr-m<sup>2</sup> to 0.079 g /hr-m<sup>2</sup>. However, during complete suspension of material, there was a noticeable increase in demand. Sludge from Mile 20 showed a utilization of 84 mg O<sub>2</sub> under quiescent conditions over 5 days, while 1300 to 1440 mg O<sub>2</sub> was utilized under completely suspended conditions.

### Heavy Metals

Slowey and Hood<sup>14</sup> measured total copper, manganese and zinc at 28 stations in the Gulf of Mexico. They observed wide ranges in concentrations with respect to depth and location, although the concentrations in the deeper waters of the open Gulf were consistently lower than in coastal areas. Manganese values varied from 0.18 to 19.0  $\mu\text{g/l}$  in the nearshore waters and from 0.05 to 0.88  $\mu\text{g/l}$  in the open waters. Sampling sites off the coast, from Galveston had ranges of copper, manganese and zinc of 0.98 to 2.0, 1.5 to 2.4 and 2.4 to 10.0  $\mu\text{g/l}$ , respectively.

Hann and Slowey<sup>15</sup> reported that the metal composition of Galveston Bay sediments was uniformly distributed. Sediments near the Houston Ship Channel and Texas City showed higher concentrations, although iron and manganese concentrations in the bay were similar to other estuarine systems. Only zinc was found to exceed the US EPA criterion of 75 mg/kg dry weight for dredged material disposal.<sup>16</sup> The US Army Corps of Engineers<sup>17</sup> found that Zn levels in the Houston Ship Channel were also in excess of the US EPA criterion.

The Corps of Engineers<sup>18</sup> determined mercury, lead, and zinc concentrations in their evaluation of the suitability of Texas City Channel sediments for open-water disposal. They found 0.44 to 2.42 mg/kg of mercury, 101 to 173 mg/kg of lead and 29.8 to 116.3 mg/kg of zinc. The observed levels of lead exceeded the US EPA, Region VI criterion (50 mg/kg dry weight) for open-water disposal of dredged sediments. Mercury levels at four of the five sampling stations also exceeded the criterion for mercury (1.0 mg/kg dry weight).<sup>16</sup>

### Nitrogen and Phosphorus Compounds

The Bernard-Johnson Inc. report<sup>10</sup> summarized the average nutrient (nitrogen and phosphorus) concentrations for the Corpus Christi Bay, San Antonio Bay and Galveston Bay areas. Based on nitrogen-to-phosphorus ratios, phosphorus would not likely be limiting algal growth in these areas. The data also showed that more nitrogen was available in Galveston Bay than in other bays studied. In the bioassays using Galveston Bay water, nitrogen was the only nutrient to significantly stimulate phytoplankton growth. They also found that during summer, only total nitrogen concentrations had a significant correlation with the species diversity index.

Copeland and Fruh<sup>19</sup> reported that at different locations in Galveston Bay, the inorganic nitrogen concentrations were below 0.3 mg/l throughout the year. Concentrations were highest in samples collected at the mouth of the Houston Ship Channel. They decreased steadily for samples taken further out in the bay, indicating dilution by mixing. Also, they found the nitrogen-to-phosphorus ratio to be below 10:1. Addition of nitrogen to Galveston Bay water samples caused significant phytoplankton growth. This and the low nitrogen concentrations observed indicated that nitrogen was probably the limiting nutrient. Using nutrient data from monthly chemical analyses of 28 stations in Galveston Bay, they found that nitrogen, iron and silica would be the nutrients most likely to limit phytoplankton growth in the bay. Comparison of the total P concentrations in samples collected at Bolivar Roads (the most seaward sampling location) showed the molar ratio of nitrogen to phosphorus to be less than 4.4:1. This indicated that phosphate probably was not the limiting nutrient in that area.

From algal bioassay studies done by Copeland and Fruh,<sup>19</sup> the indications were that some factor other than nutrient availability (such as light penetration or a growth inhibitory substance) was responsible for limiting algal growth in the area. Nitrogen generally appeared to be the only nutrient that significantly stimulated phytoplankton growth. This study also included algal bioassays on mixtures of Dickinson Bay water (which is similar in nutrient content but lower in salinity than Bolivar Roads water) and filtered Houston Ship Channel water. Up to ratios of 75:100 (Houston Ship Channel water:Dickinson Bay water), phytoplankton growth increased; when ratios of 100:100 were assayed, growth was less stimulated. They found that the higher nutrient (i.e., nitrogen) content of Houston Ship Channel water stimulated growth to the point where toxic substances became inhibitory.

According to the Corps of Engineers Galveston District,<sup>20</sup> high turbidity associated with open-water dredged material disposal reduces photosynthetic activity, and this reduction causes a corresponding reduction in the food supply at the bottom of the food chain. However, decreases in photosynthetic activity due to increased turbidity may somewhat counterbalance increases in productivity resulting from the elevation of nutrient levels caused by the resuspension of sediments.

At the Galveston Bay Entrance Channel dredging sites, dredging operations would be expected to increase turbidity.<sup>21</sup> It was felt, however, that the increase would be insignificant compared to the turbidity normally found on a windy day.

In a report on the Gulf Intracoastal Waterway, the Corps of Engineers<sup>20</sup> presented data on sediment samples collected from the Texas City Channel to North Deer Island.

In 22 samples total Kjeldahl nitrogen concentrations ranged from 360 to 1300 mg N/kg, and only five samples had concentrations over 1000 mg N/kg. One sample from Chocolate Bayou and one from the channel extending from Port Bolivar to High Island had concentrations in excess of 1000 mg N/kg, whereas all sediment samples from Offatts' Bayou were lower than the US EPA proposed dredged material disposal criterion of 1000 mg N/kg.<sup>16</sup>

El-Sayed *et al.*<sup>22</sup> reported nitrate concentrations in the surface waters of the Gulf of Mexico ranging from 0.05 to 2.20 µg-at./l (0.0007 to 0.03 mg/l as N) with a mean of 0.23 µg-at./l (0.003 mg/l as N).

From an overall point of view, this survey of the relevant literature leads to the conclusion that the concentrations of nitrogen compounds in water and sediment on the Texas Gulf Coast are extremely variable between locations, and even from station to station. Total nitrogen concentrations were higher in the Houston Ship Channel and decreased gradually toward the bay.

Several environmental impact studies were conducted on maintenance dredging on the Texas Gulf Coast to provide information on concentrations of chemical contaminants. Texas City Channel sediments were collected in June 1971.<sup>23</sup> Kjeldahl nitrogen concentrations were found to range from 170 to 2500 mg N/kg. In all but one sample, they exceeded the EPA criterion of November 1973 for open-water disposal of dredged sediments.<sup>16</sup> When water and sediment samples were collected from the Houston Ship Channel from March 16-23, 1972<sup>17</sup> Kjeldahl nitrogen concentrations in the sediments ranged from 120 to 1830 mg N/kg. In the water samples, they ranged from 0.29 to 4.49 mg/l. In

another study<sup>21</sup> Kjeldahl nitrogen concentrations in the sediments collected from Galveston Harbor and the Galveston Bay Entrance Channel ranged from 710 to 1200 mg N/kg. Ammonia ranged from 36 to 100 mg N/kg.

In 1973, the Corps of Engineers<sup>23</sup> studied two sediments taken from the channel between Bolivar Roads and Port Bolivar. Before dredging, total Kjeldahl nitrogen in one sediment was in excess of the EPA proposed criterion.<sup>16</sup> Total Kjeldahl nitrogen levels increased in two water samples collected during dredging and were higher than dredging day ambient levels in samples collected 20 days after dredging. Sediment samples taken after dredging showed low levels of most contaminants studied.

El-Sayed et al.<sup>22</sup> determined surface phosphate concentrations in the surface waters of the Gulf of Mexico. They found that during the study period 1964-1971, phosphate concentrations in the open Gulf of Mexico ranged from almost undetectable levels to 2.66 µg-at./l (0.082 mg P/l). The west-central and southwestern Gulf showed surface phosphate concentrations generally less than 0.5 µg-at./l (0.016 mg P/l).

Phosphate concentrations in the upper 200 m were higher in the central and western areas of the open Gulf than in the eastern part, where circulation was less restricted. In general, three nutrients (phosphate, nitrate and silicates) showed low concentrations in the upper 100 to 200 m, substantial increases between 200 m and 700-800 m and small decreases after a maximum near 1000 m. El-Sayed et al.<sup>22</sup> found that this distribution appeared to correspond to the vertical distribution of the water masses in the Gulf: Subtropical Underwater, Subantarctic Intermediate Water, and the North Atlantic Deep Water, respectively. At several stations the vertical distribution of

phosphate also appeared to be inversely related to the D.O. content. The depths of the low oxygen values generally seemed to correspond to maximum nutrient concentrations. This, according to El-Sayed et al.,<sup>22</sup> is commonly encountered in oceanic regions. In the open Gulf, they found no discernible seasonal fluctuations in phosphate concentrations. They observed the frequently encountered contrast between primary productivity in inshore and offshore waters. Inshore primary productivity values were nearly twice those of the offshore waters.

Copeland and Fruh<sup>19</sup> found the mean annual total P concentrations for 1969 in the Galveston Bay area ranged from 0.2 mg P/l at the mouth of Galveston Bay to 2.0 mg P/l at the mouth of the Houston Ship Channel (HSC). The gradient found between the two above points was attributed to dilution of the HSC water with Gulf of Mexico water. From data obtained during their regular monthly sampling of six locations in Galveston Bay during 1969, the low to high ranges for each month were presented. This data showed that the Morgan's Point (HSC) location had the highest total P concentration and the greatest range of concentrations during each month. During the year, concentrations ranged from 0.43 to 2.75 mg P/l. In the Texas City Channel, total P concentrations ranged from 0.10 to 0.59 mg P/l during the sampling period; highest concentrations were found in February and May. Total P concentrations found at Hannah's Reef in Galveston Bay showed very narrow ranges of concentrations during each month's samplings (a 0.16 mg P/l spread or less except for March) relative to the other stations. Over the entire year, 1969, concentrations there ranged from 0.06 to 1.63 mg P/l with the greatest concentrations found during March and June. The Bolivar Roads station (at the mouth of Galveston Bay) generally had low variability each month and had total P concentrations ranging from 0.04 to 0.7 mg P/l

during 1969. Highest concentrations were found during April, May and September.

The vast majority of the Corps of Engineer and other environmental statements did not include data on phosphorus concentrations.

#### Organic Compounds

There are few studies on organic matter in the nearshore waters and sediments of the Gulf of Mexico near Galveston, Texas. The Texas Water Quality Board<sup>12</sup> reported that in the Galveston Bay area, the bulk of the industrial discharges belong in refining and organic chemical categories. Several of the environmental statements issued by the U. S. Army Corps of Engineers included data on general organic parameters such as total volatile solids (TVS), chemical oxygen demand (COD), total organic carbon (TOC) and oil and grease. None of these parameters measure strict chemical categories, but each includes several organic compounds with varying chemical and physical properties.

The 1971 US EPA bulk criteria for polluted sediments included the following maximum limits for the general organic parameters in mg/kg based on dry weight: 60,000 for TVS, 50,000 for COD and 1500 for oil and grease.<sup>24</sup> The US EPA, Region VI proposed criterion for TVS was 80,000 mg/kg dry weight.<sup>16</sup> In June 1971 sediment and water samples were collected from the Texas City Channel to North Deer Island and were analyzed for TVS, COD and oil and grease.<sup>18</sup> The water samples contained TVS ranging from 5860 to 6900 mg/l and COD ranging from 180 to 230 mg/l. Twenty-two sediment samples contained TVS ranging from 23,700 to 73,900 mg/kg, COD ranging from 9,300 to 46,300 mg/kg and oil and grease ranging from 109 to 2,440 mg/kg. All sediment data were based on dry weight.

Water samples collected from the Gulf Intra-coastal Waterway<sup>20</sup> in December 1972 contained TVS ranging from 5,800 to 6,500 mg/l, COD ranging from 40 to 68 mg/l

and oil and grease ranging from 22 to 28 mg/l. Sediment samples from the same area contained TVS ranging from 2,600 to 6,000 mg/kg, COD ranging from 1,500 to 11,000 mg/kg and oil and grease ranging from 550 to 670 mg/kg.

In February 1974, water and sediment samples were collected from the Freeport<sup>25</sup> area by the Corps of Engineers and were analyzed for TVS, COD and oil and grease. The water samples contained TVS ranging from 6,700 to 7,600 mg/l, COD ranging from 22 to 193 mg/l and oil and grease ranging from <1.0 to 60 mg/l. The sediment samples contained TVS ranging from 44,900 to 60,000 mg/kg, COD ranging from 5,000 to 27,200 mg/kg and oil and grease from 630 to 1,500 mg/kg.

During the months of January to May 1973, the U. S. Army Corps of Engineers<sup>23</sup> monitored water and sediment during dredging operations undertaken between Bolivar Roads and Port Bolivar. Before dredging, three water samples had mean concentrations of TVS, COD and oil and grease of 16,500, 81.3 and 15.7 mg/l, respectively. During dredging, seven water samples had mean concentrations of TVS, COD and oil and grease of 5,185, 111 and 52.1 mg/l, respectively. After dredging, three water samples had mean concentrations of TVS, COD and oil and grease of 5,636, 28 and 57.7 mg/l, respectively. These data showed that TVS had a tendency to decrease during and after dredging. It should be mentioned that COD values in samples of high chloride content (>1,000 mg/l) are not accurate. The oil and grease data showed a tendency for increase during and after dredging. Three sediment samples collected before dredging had mean concentrations of TVS, COD and oil and grease of 3,200, 1,570 and 1,056 mg/kg, respectively. After dredging, three sediment samples had mean concentrations of TVS, COD and oil and grease of 1,230, 577 and 807 mg/kg, respectively.

In May 1974, seven sediment samples were collected from the Galveston Harbor Channel.<sup>21</sup> They contained TVS ranging from 1,200 to 5,500 mg/kg, TOC 3,300 to 3,400 mg/kg, COD ranging from 1,300 to 20,000 mg/kg and oil and grease ranging from 84 to 130 mg/kg.

This review of the literature, in conjunction with the results of various studies has led to the conclusion that disposal of sediments dredged from the Galveston Bay Entrance Channel would likely have little or no influence on water quality at the disposal site. Some contaminants, such as ammonia and manganese, would probably be released in readily measurable amounts; however, because of the intermittent nature of disposal operations associated with hopper dredging in the Galveston Bay Entrance Channel, the release of these contaminants would not likely have a significant adverse effect on water quality in the disposal site water column.

This report presents the results of an intensive field study designed to evaluate whether the conclusions based on the literature review are correct for dredged material disposal in the region of the Galveston Bay Entrance Channel.

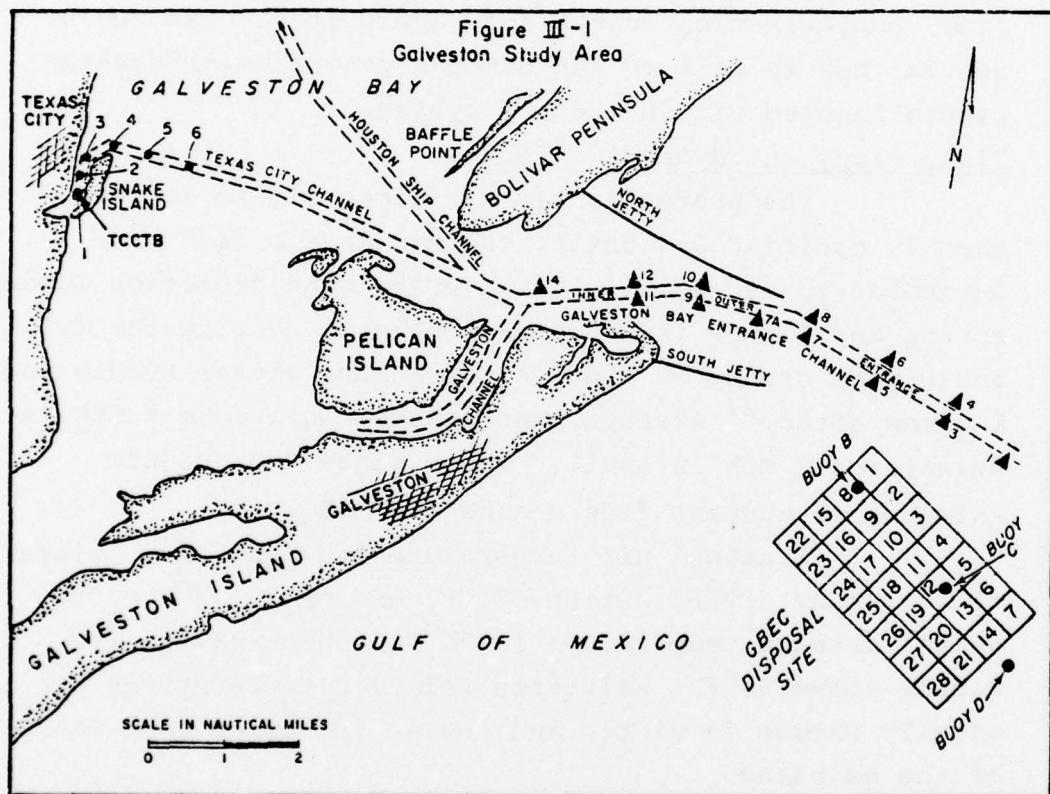
### PART III: CHARACTERISTICS OF THE STUDY AREA AND EXPERIMENTAL TECHNIQUES

#### Characteristics of Study Area

The study area was located immediately southeast of the GBEC South Jetty (Figure III-1). The disposal area forms a portion of a much larger sedimentological regime. This entire system consists essentially of the area off Bolivar Peninsula and the North Jetty, the area between the two jetties, the area off Galveston Island, South Jetty and the Government Disposal Grounds.<sup>26</sup> Water quality in this area is influenced both by the Gulf of Mexico and the Galveston Bay system.

The Galveston Bay complex is an estuarine system on the Texas Coast. It is comprised of several drowned river mouths and barrier island bays. This area is also one of the most economically important estuaries in the Texas Gulf Coast. Its economic importance stems from its proximity to one of the major population centers in Texas which depends on the bay for transportation of goods, waste disposal, cooling water, recreation and aesthetic appeal. Galveston Bay is also important as a major nursery and fishery area for commercially important marine species.

Tides and wind-induced currents flush the system, and periodic high intensity storms create periods of rapid change due to input from the Gulf and massive rainfall runoff. The Galveston Bay estuarine system is lined with industrial and domestic waste outfalls, urban and agricultural areas, bayous, rivers and tidal flats in addition to several small shallow embayments. Municipal and industrial effluents and land runoffs cause a substantial amount of material to be added to the bay. Many contaminants introduced into this system are incorporated into the estuarine sediments.



The multitude of industrial plants located on the Houston Ship Channel or around Texas City are major potential sources of heavy metals, organics and other contaminants to the estuary. Among these industries are pulp and paper mills, caustic and vinyl chloride plants, metallurgical, electroplating and other metal production and processing plants, paint, rubber, fertilizer, oil refineries and other types of petrochemical plants. Pesticide contamination arises from agricultural and residential use as well as the several pesticide-producing plants located within the bay system.

#### Climatology and Hydraulic Regime

The predominantly maritime climate is frequently modified by continental air masses from mid-September to mid-April. The average wind direction during spring and summer is from the southeast; during the fall and winter strong SE winds occur before winter fronts and N winds after.<sup>27</sup> Average wind speeds range from 9 mph in August to 12 mph in April. These winds can produce extremes of current flow around the GBEC.

Seasonal air temperature averages are: winter, 56°F; spring, 69°F; summer, 83°F; and fall, 72°F. The annual average temperature is 70°F; summer maxima are rarely above 90°F. Galveston Island's temperatures are usually warmer in winter and cooler in summer than those of the mainland.

The normal tide range in the area averages 1 to 1.5 feet. Diurnal and mixed tidal cycles occur. Tides of 3 to 4 feet above normal may result from strong, persistent E, SE or S winds, while strong, persistent N or NW winds can cause tidal action of 3 feet below normal. Hurricane activity can cause extreme storm tides. Information on current magnitude and direction and sediment

transport in the GBEC disposal area are available in a report by Bouma et al.<sup>27</sup>

#### Bathymetry of Disposal Area

Figure III-2, developed by Coulthard,<sup>26</sup> shows the bathymetry of the GBEC disposal site and adjacent area during March 1975. Water column depths ranged from 32 to 51 feet from the northwest to the southeast corner of the disposal area. The bottom appeared smooth, with a gradient of 5 ft/mi toward the southeast. Depth contours were evenly spaced and parallel to the coast, suggesting that the bottom sediments are actively being transported. A mound of approximately one square mile and maximum relief of 4 feet was found outside the northeast corner of the disposal area. The presence of large amounts of Beaumont clay dredged from the GBEC indicated that this mound was the result of dredged material disposal prior to the study. Additional information on the character of the sediments and bathymetry of the area can be found in Coulthard<sup>26</sup> and Bouma et al.<sup>27</sup>

#### History of Dredged Material Disposal near Galveston Bay Entrance Channel

Dredging of the GBEC has been practiced for many years. Table III-1, which summarizes the quantity of sediments disposed in this area for the fiscal years (FY) 1958-1975, shows that from about one to three million cubic yards of dredged sediments have been disposed per year during this period. Prior to 1975 the dredged sediment was distributed among three areas. One of these was located at approximately the same location as the GBEC disposal site shown in Figure III-1. The other two were located on either side adjacent to the GBEC between Buoys 3-4 and 7-8. No data are available on the amount of

**Figure III-2**  
**Bathymetry of the Galveston Bay Entrance Channel**  
**Disposal Site**

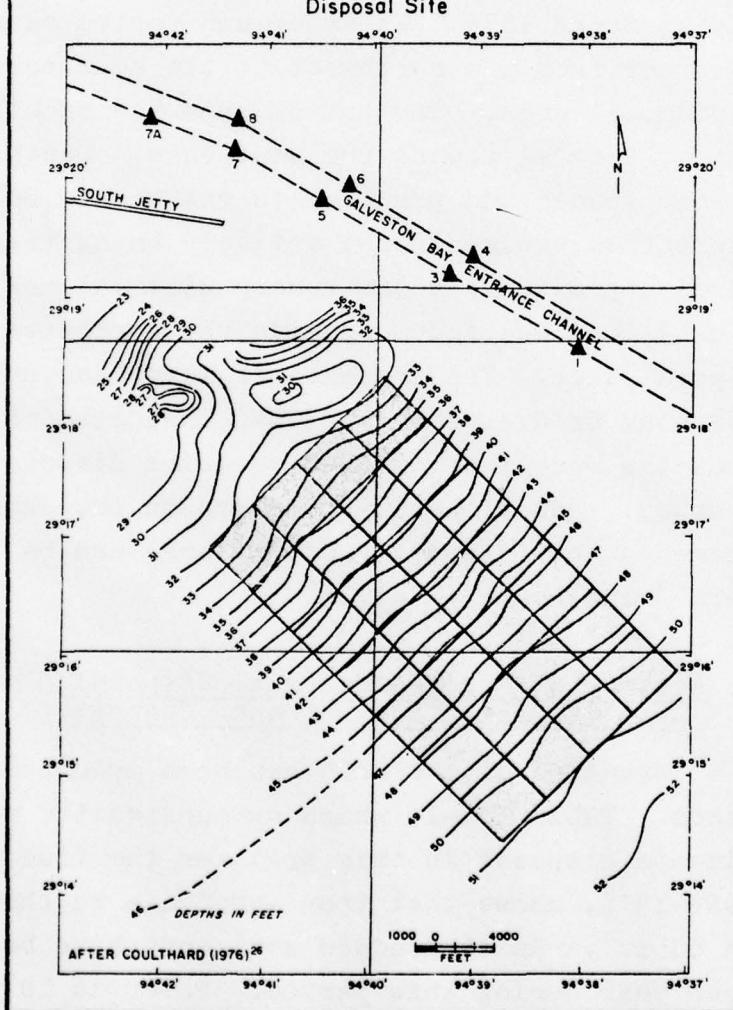


Table III-1

Recent Disposal History Offshore  
Disposal Site-Galveston, Texas

Fiscal Year*	Quantity Deposited** (cubic yards)
1958	2,664,218
1959	1,052,700
1960	1,677,200
1961	906,400
1962	2,077,408
1963	1,607,208
1964	Data not available
1965	1,159,728
1966	2,272,500
1967	1,585,690
1968	2,918,106
1969	1,355,000
1970	2,277,000
1971	1,910,021
1972	3,150,027
1973	1,892,841
1974	1,186,673
1975	1,702,292
Annual Average	1,846,765

\*Information for 1958-1973 derived from annual reports-Office, Chief of Engineers; for 1974 and 1975, derived from Galveston District of The Corps of Engineers.

\*\*Hopper dredging only - offshore disposal.

sediment disposed of at the currently designated government disposal area. It is likely to have been minimal because of the longer distances involved in the transport of the sediments from the channel to the disposal area. After 1973 all dredged sediment from the entrance channel was supposed to be placed in the designated disposal area.

In FY 1974 (July 1, 1973-June 30, 1974), dredging of GBEC sediment took place from October 1 through 13, 1973, and from January 23 through May 20, 1974. The October dredging amounted to 145,576 cubic yards and the January-May dredging, 793,351 cubic yards. In the period May 3-20, 1974, 247,746 cubic yards were dredged in the GBEC and disposed at the offshore site.

For FY 1975 (July 1, 1974-June 30, 1975), 1,702,292 cubic yards were dredged from the GBEC from July 18 to September 24, 1974. From May 7 to 13, 1975, 115,258 cubic yards were dredged there and disposed of at the GBEC disposal site. In the spring of 1976, 276,246 cubic yards of sediment were dredged from the GBEC between February 18 and March 3. This material was dumped near Buoy B.

The studies by Bouma et al.<sup>27</sup> have shown that the bathymetry of the disposal area demonstrates little or no evidence of previous dredged material disposal in the designated disposal area. Except for the previously noted mound SE of the South Jetty light (Figure III-2), these mounds are outside of the designated disposal area. Since approximately 1.8 million cubic yards per year have been disposed in this general area for the past several years, it is evident that this is a high energy environment in which there is dispersion of the dredged sediments after disposal. As discussed in a subsequent section, the

dredging situation which prevailed during the course of this study may have been somewhat atypical of normal GBEC dredging. A considerable amount of overdredging (dredging at greater depths) took place during the course of this study which removed larger amounts of Beaumont clay than normally dredged during maintenance of this channel. This clay tends to be much more cohesive than the normal shell fragment, sand, silt, and clay that usually are encountered in channel maintenance dredging. In addition to being resistant to erosion because of cohesion, the clay may, through removal of unconsolidated fines around chunks of it, form an erosion-resistant cap or pavement over the more erodible material.

#### Characteristics of Sampling Ships and the Hopper Dredge

Five vessels were used for sample collection. The Gus III of Galveston, Texas, is a 90-foot shrimp boat with a cruising speed of 8.5 knots. The Texas Star out of Galveston is an 82-foot twin-screw shrimp boat that had been modified for scientific sampling. She has a cruising speed of 13 knots. The Orca, also out of Galveston, is a 110-foot shrimp boat with a cruising speed of 10 knots. The Dutchess has a cruising speed of 20 knots. The Erin Leddy Jones is a 53-foot research vessel belonging to the University of Texas Marine Biomedical Institute in Galveston. The boat's basic design is similar to that of a shrimp boat.

The hopper dredge McFarland is owned and operated by the U. S. Army Corps of Engineers, Galveston District, Galveston, Texas. The McFarland is 300 feet long and 72 feet across the beam, the widest part of the ship. Its twin-screw propellers are powered by a 6000 horsepower diesel engine. The displacement of the loaded ship is 9270 tons, and the

designed maximum draft is 22 feet. The hopper has a maximum capacity of 3140 cubic yards and is equipped with 12 doors for disposal of the load. The dredged material is pumped into the hopper through two large side-arms (one on each side of the vessel), each 63 feet in length. This gives the McFarland a maximum dredging depth of 55 feet. The 26-inch pumps connected to each side-arm are driven by 2800 horsepower engines. Two other pumps of the same size are connected to the pump-out or water-withdrawal system.

The actual dredging was done by the two side-arms, which have large scraper-like attachments at their ends. The arms were lowered to the bottom and dragged through the substrate. The hopper pumps drew the water and sediment through pipes into the hopper. The action is similar to that of a large vacuum cleaner. The dredging operations were controlled from the bridge of the ship, where one man was assigned to control the movement of each side-arm and another to control the dumping operations.

The dredged material was pumped into the hopper section of the ship. The hopper of the McFarland does not contain compartments, as is the case with many other hopper dredges. It does have several doors which open to allow the material to drop. When the material was in the hopper, the excess water was removed by either an overflow port or pumps. The hopper is also equipped with recirculating pumps which pump jets of water into the hopper to help clean it after the doors have opened and to keep the materials in suspension during transport.

#### Experimental Techniques

##### In Situ Measurement of the Water Column

The Hydrolab Model 6D surveyor was used for monitoring of temperature, D.O., conductivity, and pH at specific depths in the water column. Temperature of the

water was measured with a thermistor temperature probe. Concentrations of D.O. were measured with a membrane-covered, passive polarographic probe. The electrode was calibrated by either using the standard air calibration procedures (using atmospheric oxygen as a reference) or by using air-saturated water as a reference. The temperature dependence of the electrode was compensated by internal thermistors. The range of the electrode was from 0 to 20 mg/l.

The electrical conductivity of the water was measured by a "four-electrode" probe. The probe was electronically controlled to provide linear conductivity readings continuously corrected for water temperature deviations from 25°C. In the field an internal standard was used for calibration of the probe. The internal calibration of the probe was checked against a 0.1 M solution of KCl in the laboratory. The probe had a range of 0 to 100,000  $\mu$ mhos/cm.

The pH of the water was measured by a pH and reference electrode. The reference probe was a solid-state configuration type with no pressurization requirements or electrolyte replenishment. The system was such that it had a standard internal correction for changes in the water temperature. The meter was standardized against standard buffers of 7.0 and 9.18 pH units. Depth was also determined using the Hydrolab unit, which contained an electrical pressure transducer system. The range of the system was 0 to 20 meters.

#### Determination of Optical Properties of the Water Column

The experimental procedures used in this study encompassed several methods for the determination of the optical properties of the water column. These methods included the use of nephelometric turbidity measurements,

Secchi depth and percent transmission. All laboratory turbidity measurements were performed using a Hach turbidimeter (Model 2100A). In the field, optical properties were measured with a Secchi disk and a transmissometer.

The Hach turbidimeter is a nephelometer which has a range of 0.01 to 1000 nephelometric turbidity units (NTU's). The standards by which this instrument are calibrated are rated in NTU's, which are approximately equivalent to Formazin Turbidity Units (FTU's) and Jackson Turbidity Units (JTU's). The standards were calibrated against Formazin.

Secchi depths were measured at each disposal site prior to disposal of dredged material. These depths were measured by gradually lowering a Secchi disk (20 cm diameter) until the black and white quadrants were no longer distinguishable, recording that depth, lowering the disk one meter and then gradually raising the disk until the quadrants were distinguishable, recording that depth and then taking the average of the two depths.

The turbid plumes of suspended material at the disposal sites were detected by measuring percent light transmission as a function of time. The transmissometer system utilized in the field studies was a Model 612 S Hydro-Products instrument. This system consists of interchangeable 1-m and 10-cm light paths, a Model 512 readout module and a power supply (nickel-cadmium batteries). The 10-cm light path was used throughout the field studies.

The Hydro-Products transmissometer was air calibrated in this study. This method of calibration is based on the principle that transmission of light in the air is 92 percent. Once the instrument was calibrated, it was not adjusted unless it was disassembled, the windows cleaned, and the instrument was reassembled. If the transmissometer was to be used for more than one

disposal operation per day, the sensor unit was kept submerged to prevent a film of salts and suspended sediment from adhering to the windows.

#### Sample Collection Techniques

Several different techniques and types of equipment were used to collect water samples. A Van Dorn type water sampler was employed when only a sample profile of the water column was taken. A large number of samples were taken during disposal by using a Little Giant submersible pump Model 3E12N and appropriate length of rubber garden hose.

Sediment samples were taken with three different types of grab samplers: the Ponar grab, the Petersen grab and a box corer. The majority of the sediment samples were taken by D. Harper using the box corer in conjunction with his biological sampling of benthic organisms. Polychaetes were obtained by a sampling dredge which was dragged for several hundred meters across the bottom. Polychaete tubes were picked from the sediment by hand using a water jet to remove excess sediment. The organisms were extruded from their tubes and placed in clean sea water for the purpose of purging their guts of sediment. The time required for organisms to completely purge sediment from their intestinal tracts was not determined.

#### Laboratory Procedures

This section presents a description of the techniques used for the laboratory analysis of the water and sediments obtained in this study.

#### Analytical Procedures for Trace Heavy Metals

Water samples. Water samples for soluble heavy metals determination were filtered through a  $0.45\text{-}\mu$  pore size Millipore filter and acidified to pH 1 with HCl or  $\text{H}_2\text{SO}_4$ . Water samples for total metals were acidified to pH 1 and allowed to stand 24 hours before analysis.

Atomic absorption techniques were used to determine trace heavy metals in the samples. Models 303 and 360

Perkin-Elmer Atomic Absorption Spectrophotometers (AAS) were utilized. An air-acetylene flame was used for iron (Fe), chromium (Cr), nickel (Ni), cadmium (Cd), lead (Pb), copper (Cu), zinc (Zn), and manganese (Mn). Mercury (Hg) was determined using the cold-vapor technique on the Model 360 AAS or on a Model 50 Perkin-Elmer/Coleman Mercury Analysis system. Arsenic (As) determination was performed on the Heated Graphite Atomizer on the Model 360 AAS.

Water samples for all metals analyzed except mercury and arsenic were chelated with ammonium pyrrolidine dithiocarbamate (APDC) and concentrated by extraction with methyl isobutyl ketone (MIBK), as recommended by Standard Methods.<sup>28</sup> Either 150 or 200 ml of sample were extracted after adjustment of the pH to 2.5 to  $\pm$  0.2 using a 0.2 percent bromophenol blue solution as indicator, and dropwise addition of 30 percent NH<sub>4</sub>OH and 2.5 percent HCl.

A freshly prepared 2 percent aqueous solution of APDC was twice extracted with MIBK to remove impurities. When using a 150-ml sample volume, a 5.0-ml portion of APDC was added to the sample in a 500-ml or 250-ml volumetric flask and mixed. This was followed by addition of 10.0 ml of MIBK and vigorous shaking on a wrist-action shaker for 5 minutes. The phases were allowed to separate; deionized distilled water was carefully added to bring the organic layer into the neck of the flask. This allowed direct aspiration of the sample into the air-acetylene flame. Blanks and standard additions in waters of appropriate matrices were carried throughout the procedure.

Determination of mercury was based on the Hatch and Ott procedure as adapted by the US EPA.<sup>29</sup> Duplicate 150-ml or 200-ml samples were placed in BOD bottles and treated with 5 ml 35 percent HNO<sub>3</sub> and 5 ml 50 percent H<sub>2</sub>SO<sub>4</sub> in the presence of KMnO<sub>4</sub>. It was found that for these samples two

drops of 5 percent  $\text{KMnO}_4^-$  was sufficient for complete oxidation. The excess  $\text{MnO}_4^-$  was reduced by the addition of 5 ml of 1.5 percent  $\text{NH}_2\text{OH}\cdot\text{HCl}$ . A 5 ml portion of the 10 percent  $\text{SnCl}_2$  was added immediately before analysis. The mercury vapor was then circulated by air pump into the light path for absorption measurement.

Arsenic analysis was done by direct introduction of the water sample into the graphite tube of the Heated Graphite Atomizer on the Model 360 AAS. To prevent possible salt matrix interference, 20  $\mu\text{l}$  of a solution of 1.0 g/l Ni and 50 percent  $\text{NH}_4\text{NO}_3$  (w/v) were added to the tube with each sample. This mixture permitted use of higher temperatures during ashing and atomization, thereby removing the salt interference. The HGA-2100 settings listed in Table III-2 are after Ediger *et al.*<sup>30</sup>

Table III-2

HGA-2100 Instrument Setting for Arsenic  
Determination in Seawater\*

Cycle	Time (sec)	Temperature (°C)
Dry	30	120
Char	60	1100
Atomize	10	2700

\*With addition of 20- $\mu\text{l}$  solution of 1000 mg/l Ni - 50 percent  $\text{NH}_4\text{NO}_3$ .

After Ediger *et al.*<sup>30</sup>

Sediment samples. Sediments were dried at 60°C and then ground into a fine powder. This powder was allowed to dry at 60°C for at least one hour. For all heavy metals except Hg and As, triplicate or duplicate 1.0-g samples were wet digested in Teflon beakers with 10 ml  $\text{HNO}_3$ , 10 ml 48 percent HF (the HF addition was repeated) and 10 ml 70 percent  $\text{HClO}_4$ . The beaker was covered during the  $\text{HClO}_4$  step, and heating continued 20 minutes after fumes appeared. After cooling, 5 ml HCl were added, and the clear solution was diluted to 50 ml volumetrically. Blanks were carried through the procedure.

For determination of total mercury in sediments, duplicate 0.2-g portions of the dried sediment were placed into BOD bottles. To these, 5 ml  $\text{H}_2\text{SO}_4$ , 2 ml  $\text{HNO}_3$  and 5 ml saturated  $\text{KMnO}_4$  were added. The bottles were covered with heavy-duty aluminum foil and autoclaved at 121°C, 15 pounds pressure for 15 minutes. After cooling, 100 ml of deionized water and 6 ml of 1.5 percent  $\text{NH}_2\text{OH}\cdot\text{HCl}$  were added, and the sample was analyzed as previously described. Arsenic analysis was done by direct introduction of the digested sediment sample into the graphite tube with the  $\text{Ni-NH}_4\text{NO}_3$  mixture. The procedure followed was the same as that for water samples outlined above.

All wavelength settings used in this study were those recommended in the Perkin-Elmer instrument manual for the respective instruments. Where necessary, the deuterium arc background corrector was used to compensate for matrix interferences encountered in the analysis of these samples. Detection limits are listed in Table III-3.

Polychaete samples. Polychaete samples were dried at 50°C and weighed as a composite sample. The mass was wet-digested with 15 ml  $\text{HNO}_3$  and 7 ml  $\text{HClO}_4$  until white fumes appeared. After fumes appeared, heating continued for 20 minutes. After cooling, the samples were transferred to a 25-ml volumetric flask and diluted to the mark with deionized water. The samples were then analyzed as aqueous preparations.

Table III-3  
Detection Limits for Heavy Metals  
Analytical Methods

Element	Detection Limits ( $\mu\text{g/l}$ )			
	MIBK Extracts on Air-Ac Flame	Aqueous on Air-Ac Flame	Cold-Vapor Technique	HGA Furnace
Copper	1.0	5	-	-
Cadmium	0.5	2	-	-
Iron	5.0	10	-	-
Manganese	10.0	8	-	-
Lead	1.0	20	-	-
Zinc	1.0	3	-	-
Nickel	2.0	10	-	-
Chromium	2.0	8	-	-
Arsenic	-	-	-	2.0
Mercury	-	-	0.001	-

Dash (-) indicates procedure not applicable.

Interstitial water procedures and ammonium acetate extraction. Interstitial water was obtained from sediments by centrifugation. Sediments were homogenized and transferred to centrifuge bottles under a nitrogen atmosphere. They were then centrifuged at 9,000 rpm at  $4^{\circ}\text{C}$  for 5 minutes. The water was filtered through  $0.45\text{-}\mu$  pore size filters and acidified for metal analysis.

For the extractable fraction, a 15 g sample of sediment of known moisture content was weighed and transferred into the centrifuge bottle. This was shaken for 5 minutes with 83 ml of 1 N  $\text{NH}_4\text{OAc}$  (ammonium acetate), then centrifuged at 2000 rpm at  $4^{\circ}\text{C}$  for an additional 5 minutes. The supernatant was decanted. The sample was then extracted two more times in the same manner. The resulting supernatants were mixed with the first, and for analysis the entire

mixture was diluted with 1 N  $\text{NH}_4\text{OA}_\text{C}$  to 250 ml with deionized water.

The HGA-2100 Heated Graphite Atomizer for the Perkin-Elmer 360 Atomic Absorption Spectrophotometer was used for all metal analyses of interstitial waters. The deuterium arc background corrector was used in all analyses. Where direct injection failed to give a detectable signal, MIBK-APDC extraction was used to concentrate the sample. Operating conditions used were those suggested by Chen *et al.*<sup>31</sup> as shown in Table III-4.

Table III-4  
Operating Conditions for HGA-2100

	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn
<b>Drying</b>								
Temp °C	125	125	125	125	125	125	125	125
Time (sec)	30	30	20	20	20	20	30	20
<b>Charring</b>								
Temp °C	400	1250	950	1250	1100	1200	550	500
Time (sec)	30	45	30	60	60	40	40	50
<b>Atomizing</b>								
Temp °C	1500	2600	2550	2400	2400	2550	2000	2000
Time (sec)	8	6	8	7	5	7	7	6

From Chen *et al.*<sup>31</sup>

Analytical Procedures for Nitrogen Compounds

Ammonium in water. A specific ion-electrode procedure was used for ammonium analyses of water samples. (Orion Model 801A Meter and Model 95-10 Ammonia Electrode). The procedure required conversion of the  $\text{NH}_4^+$  to  $\text{NH}_3$  by

adjusting the pH to greater than 11 with NaOH. Using a standard additions procedure, the change in potential was observed when a known volume of standard NH<sub>3</sub> solution was added to the sample. The concentration of unionized ammonia in the original sample was then calculated from the measured change in potential and from the pH of the solution. This system was found to measure ammonium concentrations reliably down to 0.05 mg N/l, with detection capabilities as low as 0.01 mg N/l in some cases.

As the study advanced, a detection limit of 0.05 mg N/l was set for ammonium analyses to avoid the excessively long time required in processing samples with concentrations below this value. In raising the detection limits from 0.01 mg N/l to 0.05 mg N/l, the sample processing time could be shortened by about 5 minutes per sample. According to the tables of the fraction of ammonia in the undissociated form, unionized ammonia comprises less than 10 percent of the total ammonia in the pH and salinity range of the water samples examined.<sup>32</sup> Thus, even when the detection limit was raised to 0.05 mg N/l, it was well below the recommended criterion for the chronic toxicity of unionized ammonia.<sup>33</sup>

The results from the electrode are reproducible to better than  $\pm$  0.5 mv or  $\pm$  2 percent of the concentration. Throughout this report, the term ammonium is used to represent the total ammonia in solution and includes both NH<sub>4</sub><sup>+</sup> and unionized ammonia.

Nitrate in water. For nitrate, the Brucine Method as described in Standard Methods was followed.<sup>28</sup> The absorbance was determined on a Bausch and Lomb Spectronic 20 or Spectronic 70 spectrophotometer at 410 nm. This method was found to measure nitrate concentrations reliably down to a detection limit of 0.04 mg N/l.

Organic nitrogen in water. The ammonium electrode system was also used to determine Kjeldahl N after digestion. Unfiltered samples were first digested on a micro-Kjeldahl rotary digester (American Instruments Company) according to Standard Methods,<sup>28</sup> then distilled into 4 percent boric acid solution using a steam distillation unit (American Instruments Company). Total organic N values were obtained by subtracting the ammonium N concentration from the Kjeldahl N concentration, which was determined separately. Organic N values are reported as mg N/l.

Ammonium in sediment. Wet sediment (1-3 g) was transferred to a flask by a polyethylene syringe and tube assembly. Deionized water was added to keep the sediment in suspension. The sample was distilled after adjusting the pH with NaOH - Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub> reagent, and the distillate collected in boric acid. The final ammonium concentration was measured either by the specific ion electrode method<sup>34</sup> or by the titrimetric method.<sup>28</sup>

Organic nitrogen in sediment. The Kjeldahl N and ammonium concentrations were determined separately, and the ammonium concentration was subtracted from the Kjeldahl N concentration to obtain the organic nitrogen content of the sediment. The procedure for determining Kjeldahl N in the sediment was developed as a combination of digestion procedures presented in Jackson,<sup>35</sup> Black et al.<sup>36</sup> and APHA et al.<sup>28</sup> The sediment sample to be analyzed was first homogenized by vigorous hand mixing. A syringe and tygon tubing sample apparatus was used to transfer 1-g aliquots of the wet sediment into the bottom of tared micro-Kjeldahl digestion flasks. The weight of the added sediment was then determined. Concurrently, sediment samples were transferred to tared evaporating dishes and oven dried at 105°C to determine the percentage dry weight of the sediments.

After weighing, about 1 ml of deionized water was added to each digestion flask, and the mixture was swirled and allowed to stand for 30 minutes. One ml of  $\text{KMnO}_4$  was added, followed by 2 ml of 50 percent  $\text{H}_2\text{SO}_4$ . Next, one drop of octyl alcohol and 0.5 g of reduced iron were added, and the mixture in the flask was heated to boiling for 45 minutes, then cooled. Finally a mixture of  $\text{K}_2\text{SO}_4$ ,  $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$  and Se was added. The flasks were digested on the rotary digestion unit for 4 to 5 hours. After cooling, about 20 ml of deionized water were added, and the ammonium in the flask was distilled into boric acid solution. This solution was analyzed with the selective ion electrode system for ammonia after pH adjustment with NaOH. The values are reported as mg N/kg of dry sediment.

Cesium chloride extractable ammonium. Approximately 10 g of sediment was weighed and extracted with 100 ml of 0.1 N CsCl solution for one hour. Then the sample was centrifuged at 4000 rpm for 5 minutes at  $4^\circ\text{C}$ . The supernatant was collected for ammonium analysis.

Interstitial water. Interstitial water was taken from selected sediment samples. The sediment was homogenized and transferred into centrifuge bottles under a nitrogen atmosphere and centrifuged at 9000 rpm and  $4^\circ\text{C}$  for 5 minutes. A portion of the supernatant was filtered and acidified under a nitrogen atmosphere and analyzed for ammonium following the procedure outlined previously.

#### Analytical Procedures for Phosphorus Compounds

Water. Soluble orthophosphate and total phosphate content of water samples were determined using the Ascorbic Acid method.<sup>28</sup> Soluble ortho P was measured on filtered samples (using 0.45- $\mu$  pore size filters). Unfiltered samples were digested according to the Persulfate Digestion Procedure<sup>28</sup> before analysis for total P.

Detection limits were 0.01 or 0.02 mg P/l for soluble ortho P and 0.02 to 0.05 mg P/l for total P. All values are reported as milligrams of phosphorus per liter.

Sediments. Sediments to be analyzed for total phosphorus were first dried at 105°C for at least 12 hours. The dried sediments were cooled in a dessicator and were then ground to a fine powder. Either 0.5 g or 2 g of the powdered sediments was weighed into a 125-ml Erlenmeyer flask. Ten ml of HNO<sub>3</sub> were added, and the flask was heated to near boiling for 20 to 30 minutes. After the flask was cooled to room temperature, an additional 10 ml of HNO<sub>3</sub> and 10 ml of HClO<sub>4</sub> were added to the flask. This mixture was heated at boiling for 20 minutes or until the formation of heavy white fumes. At this point, 1 to 2 ml of HClO<sub>4</sub> were used to wash down any particles adhering to the sides of the flask, and the mixture was digested for an additional 5 minutes. The digestate was then cooled, quantitatively transferred to a 250-ml volumetric flask, and brought to volume. This procedure is similar to those suggested by Jackson<sup>35</sup> and Black.<sup>37</sup>

The suspended matter in the volumetric flask was allowed to settle, and the supernatant was subsampled for analysis. Generally, 5 ml of sample was withdrawn from the flask for each aliquot. The aliquot was neutralized with NaOH (with phenolphthalein indicator), and the volume was adjusted to 20 ml. The sample was then analyzed using the Ascorbic Acid reduction method.<sup>28</sup> Values are reported as micrograms of phosphorus per gram dry sediment. No correction for arsenate was made. Based on the total arsenic of the sediments, the potential magnitude of error due to the arsenic interference is insignificant.

Interstitial water. Sediment samples were homogenized and centrifuged at 9000 rpm and 4°C for 5 minutes. A portion of the supernatant (interstitial water) was filtered and acidified under a nitrogen atmosphere and

analyzed for soluble ortho P content following the procedure outlined previously.

Ammonium acetate-extractable fraction. The ammonium acetate-extractable fraction of the sediment was obtained as described in the heavy metals section. The extract was then shaken to volume, mixed and used for ortho P analysis following the procedure outlined previously.

Determination of Carbon, Oil and Grease

Water column total organic matter was measured according to the procedure outlined in the US EPA Manual.<sup>29</sup> The instrument used was a Beckman Model 915 Organic Carbon Analyzer which measures total carbon (TC) and total inorganic carbon (TIC) in aqueous samples. The difference between the two values represents TOC. Low levels of TOC (10 mg/l or less) were directly measured on the TC channel on samples acidified to a pH of 2 with 1:1 HCl to remove inorganic carbon. Both procedures yielded comparable results. Soluble TOC represents total organic carbon samples filtered through a 0.45- $\mu$  pore size filter or centrifuged for 10 minutes at 9000 rpm.

The volume of sample injected into the instrument ranged from 20 to 150  $\mu$ l. Each sample was analyzed in triplicate. The lower detection limit for TOC was 0.5 mg/l, and the relative error ranged from 0.49 to 5.9 percent.

Sediment TC and TOC were determined on a Leco IR-12 Carbon Analyzer Model 762-500. Samples weighed from 0.5 to 1.5 g and were analyzed at least in triplicate. Total carbon was determined on homogenized air-dried samples, and TOC was determined on air-dried or oven-dried ( $40^{\circ}\text{C}$ ) samples after acidification with 1:1 HCl to pH 2 or less. Acid treatment removes inorganic carbon compounds and effects hydrolysis of some of the organic compounds. Some volatile organics may be lost during this step, so the TOC value represents the carbon

content of the nonvolatile organics in the sediment. The lower detection limit for both TC and TOC was 0.005 percent. The relative error in the TC values ranged from 2.7 to 9.4 percent, and the relative error in the TOC values ranged from 2.4 to 18.1 percent.

Oil and grease in water and sediment were analyzed according to the procedure outlined in the US EPA Manual.<sup>29</sup> Water and sediment analyzed after September 1975 were acidified to pH < 2 and freon was used as the extracting solvent. Prior to that date hexane was used as the extracting solvent and samples were not acidified to pH < 2. Samples for water and sediment analysis were usually 1 liter and 10 g, respectively. The lower detection limit for oil and grease in water was 0.5 mg/l and in sediment was 16 mg/kg.

#### Analytical Procedures for Oxygen Demand

Analytical procedures used in the oxygen demand test are detailed in Lee *et al.*<sup>3</sup> The D.O. was measured with a YSI Model 54 membrane electrode. A YSI BOD probe was used. The oxygen demand of the sediments was determined by placing a known volume of sediment in a BOD bottle containing disposal site water. Any oxidized microzone (indicated by a reddish-brown color on the surface of the sediments) was scraped off and discarded. The sediment was mixed with a glass stirring rod in the glove bag under nitrogen, and a 20-cc sample was taken with a plastic syringe that had the end removed to allow free flow of sediment into the barrel upon withdrawal of the plunger. The sediment contained in the syringe was capped with Saran Wrap and stored until oxygen demand was determined. Three ml of sediment was introduced into the BOD bottle (approximately 300-ml capacity), which contained a magnetic stirring bar. The first few milliliters of sediment in the syringe were discarded in order to ensure minimal oxidation of the sediment before its exposure to the oxygen-containing disposal site water. Test site water was added and the BOD oxygen probe

was inserted in the top of the bottle. The magnetic stirrer was started and oxygen readings were taken every minute for the first 10 minutes, and every 5 minutes for the remainder of an hour.

#### Sulfide Determination

A modified version of the iodometric titration procedure described in Standard Methods<sup>28</sup> was used for the determination of total sulfides. Gardner<sup>38</sup> modified the iodometric titration procedure by utilizing steam instead of an inert gas for H<sub>2</sub>S stripping. Bortleson<sup>39</sup> made a further adaptation. He substituted potassium biniodate for the iodine solution and carried out the determination on the AMINCO steam-distillation apparatus. These modifications are utilized in the current study.

#### Oxidation Reduction Potential

Oxidation reduction potential (Eh) was determined by placing a bright platinum electrode in the sediment. The probe was allowed to come to equilibrium before a reading was taken. The electrode readings were made on an Orion Model 801A Digital Ionalayzer against a calomel reference electrode. Readings were not corrected for half-cell values.

#### Moisture Content of Sediment

Percent dry weight was determined by first weighing the wet sediment in a pre-weighed crucible, allowing it to dry for 24 hours at 60°C, and then reweighing the crucible and contents.

#### pH Determination

A modification of the procedure outlined in Black et al.<sup>36</sup> was used for the analysis of the Galveston sediments. Twenty cc of wet sediment was used instead of the recommended 20 g of dry soil. A Beckman Model 76 pH meter was used to determine pH.

### Particle-Size Determination

Particle-size determination in this study utilized the hydrometer method presented by Black *et al.*,<sup>36</sup> and particle-size distribution was derived from summation curves plotted from the data. Particle size was separated into four overall categories: >0.05 mm, 0.05 to 0.02 mm, 0.02 to 0.005 mm and <0.005 mm. Generally, anything ranging from 0.10 to <0.05 is considered very fine sand. Particles in the range of 0.05 to 0.02 mm are considered silt. Anything under 0.002 mm is considered clay.

### Cation Exchange Capacity

The sediments were dried at 60°C and washed three times with deionized water to remove adsorbed ammonia. Further procedures were according to Black *et al.*<sup>36</sup> Basically, the procedures involved saturation of 1.0 g of sediment with 25 ml of 1 N NH<sub>4</sub>OA<sub>c</sub>. After 24 hours, the samples were rinsed with 50 ml of 1 N NH<sub>4</sub>Cl and 50 ml of isopropyl alcohol. After air drying, upon addition of 1 N NaOH, 0.1 grams of the ammonia-saturated sediment was analyzed for NH<sub>3</sub> by specific ion electrode. This procedure and calculations were recommended by Busenburg and Clemency.<sup>40</sup>

### Quality Control Measures

In general, replicate analyses (normally two or three) were performed for the water samples collected prior to and after disposal. A single analysis was performed for the samples collected during disposal operations. This is justified because these water samples were collected rapidly in succession with only short periods of time between succeeding samples. In general, quality control procedures involving replicate analyses of the same samples and of samples containing standard additions were followed in accordance with US EPA procedures.<sup>41</sup>

## PART IV: WATER COLUMN RESULTS

### Introduction

The original study plan included pre-disposal sampling in March and April in anticipation of late spring dredging operations in the Galveston Bay Entrance Channel. In March and April, however, severe weather conditions aborted several sampling trips. In early May, shortly after commencing dredging and disposal operations, the hopper dredge McFarland developed mechanical problems which forced it to go to dry dock for several months. The hopper dredge returned to Galveston and began dredging operations the last week of August.

The pre-disposal data in this report were primarily collected in the spring of 1975. These data are followed by those collected during an intensive study period associated with the disposal operations that took place in late August, early September and mid-October 1975.

The study plan called for the UTD group to set up and sample at 50 to 100 meters downcurrent from the disposal site. This was done to give an estimate of mixing and dispersion of contaminants present in the water column along the line of movement of the turbid plume generated by dredged material disposal.

The first series of disposal operations that was monitored took place in late August 1975. Another series of dumps was monitored in early September in an attempt to gather additional data on the characteristics of the water column during disposal. Large numbers of samples were collected prior to, during and after passage of the turbid plumes arising from each dumping operation.

The day following the early September sampling was a lay day (fueling day) for the McFarland. The first post-disposal data were obtained on this day. These data were taken to determine the characteristics of the water column at the dredged material disposal site approximately 12 hours after cessation of disposal in the region.

Since the sediments from the GBEC region are not generally considered significantly polluted according to US EPA bulk chemical criteria,<sup>16</sup> permission was received for the McFarland to dredge a limited amount of sediment from the TCCTB and dump it at the disposal site. These sediments were classified by the same criteria as highly polluted. Several attempts to conduct this part of the study had to be aborted because of high seas. Finally, in early October 1975, several dumps of TCCTB sediments were made by the McFarland at the disposal site. The turbid plume arising from one of these was monitored. Partial monitoring of a turbid plume arising from another dump was also achieved.

One of the problems encountered during this series of dumps as well as during the previous two study periods was that occasionally the dump would occur slightly before or after the specified time. The very compact nature of the turbid plume resulted in the turbid plume completely missing the sampling ship, which was located some 50 to 100 meters downcurrent from the dump site. A post-disposal sampling cruise was conducted in late November 1975 to see if there were any residual effects of dredged material disposal on water quality in the disposal region over one month after the last disposal operation.

Presented in this section of the report is a discussion of the characteristics of the water columns in the

dredging areas (GBEC and Texas City Channel near the turning basin) and the disposal area. The sediment data from the sites which were dredged are presented in Part V. They give an indication of the overall characteristics of the materials disposed of at the disposal site in subsequent operations. The water column studies provide an indication of the characteristics and variability of the waters in this region and thereby enable one to determine the potential significance of any effect of disposal on the characteristics of the water at the disposal site during disposal operations.

This area of the Gulf of Mexico tends to be highly variable in composition as a result of mixing of water from the Gulf of Mexico with water from Galveston Bay. Galveston Bay water contains much higher concentrations of many man-derived contaminants than that of the Gulf. Further, the GBEC is subject to strong tidal currents with typically more saline Gulf waters forming a salt wedge in the entrance channel and at the disposal area. The wedge is generally overlain with the less saline, often more contaminated Galveston Bay waters. It is with this background that one must judge whether the release of any contaminants associated with dredged sediments is having a significant adverse effect on water quality at the disposal site.

Throughout Chapters IV and V, when used in reference to data gathered in this study, the term "significance" signifies the statistical significance, usually at the 95 percent confidence level. The primary emphasis is on whether there is a statistically significant difference between two given situations. It is important to note that the statistical significance may have little or no relationship to ecological or water-quality significance. The

environmental significance of the data obtained in this study is discussed in Part VI.

#### Pre-Disposal Characteristics of Water Column

##### Optical Properties

One of the areas of concern in open-water dredged material disposal is the effect of this disposal on the optical properties of the disposal site water. With few exceptions, disposal creates a turbid cloud or plume which, in clear water, would tend to create public concern about the water quality and appearance of the water. To evaluate the environmental impact of dredged material disposal at the GBEC Disposal Site, some measurements were made of the optical properties of the water column in this area prior to any of the current disposal operations.

Table IV-1 presents the Secchi depth data obtained April through June 1975 for the GBEC and selected disposal site grid squares. The April 17 data show that the Secchi depth was 0.5 m at GBEC Buoy 7 and ranged from 0.9 to 2 m in the disposal site grid. April 17, May 7 and June 11 data for Buoys 11 and 7A showed that the GBEC Secchi depths ranged from 0.6 to 0.8 m. Less turbid water was found near Buoy 1 on April 17, May 7 and June 11 with a Secchi depth of 2.5 m found on the latter date, while Grid Square 2 water had Secchi depths on the latter date near 1 m. From these data it appears that at this time of the year, the GBEC has somewhat more turbid water than the disposal site and that the overall water clarity of the region is relatively poor. This reflects the relatively high degree of turbidity that can be found in the coastal waters of Texas at this time of year.

Table IV-1  
Pre-Disposal Galveston Bay Entrance Channel and  
Disposal Site Secchi Depth Data  
 (meters)

Sampling Location	Sampling Date (1975)			
	4/17	4/18	5/7	6/11
<b>GBEC Dredging Sites:</b>				
Buoy 11	-	0.8	0.6	0.7
Buoy 7A	-	-	-	0.8
Buoy 7	0.5	-	-	-
Buoy 1	1.0	-	1.0	2.5
<b>GBEC Disposal Sites:</b>				
G.S. 1	1.5	-	-	-
G.S. 2	1.5	-	1.0	0.8
G.S. 6	2.0	-	-	-
G.S. 7	0.9	-	-	-
G.S. 8	1.5	-	-	-
G.S. 9	1.5	-	-	-
G.S. 13	1.0	-	-	-
G.S. 15	2.0	-	-	-
G.S. 16	1.5	-	-	-
G.S. 23	1.5	-	-	-

Dash (-) indicates no data available.

Some turbidity data were obtained on samples collected on March 18, April 18, May 7, May 23, June 11, and September 20. These data are presented in Table IV-2. (See Figure III-1 for location of sampling stations.) In general, they show the same pattern as Secchi data; the least turbid water is at Buoy 1 and G.S. 2 and the

Table IV-2  
Pre-Disposal Turbidity Measurements for  
Galveston Study Area Water Samples  
(NTU)

Sampling Location	March 18			April 18			Sampling Dates (1975) and Depths		
	S	M	B	S	M	B	S	M	B
TCCTB 1	0.9 (s)	-	-	-	-	-	-	-	-
TCCTB 2	4.6 (s)	-	-	-	-	-	-	-	-
TCCTB 3	10 (s)	-	-	-	-	-	-	-	-
TCCTB 4	-	-	-	-	-	-	-	-	-
TCCTB 5	-	-	-	-	-	-	-	-	4
TCCTB 6	-	-	-	-	-	-	-	-	3.8
HSC Buoy 100	-	85	130	-	-	-	-	-	4.7
Morgan's Point	-	27.5	280	-	-	-	-	-	5.3
HSC	-	100	-	-	-	-	-	-	-
Buoy 11	-	18	7.6	74 (7)	13 (12)	9.3	14	15.5 (6)	20 (11)
Buoy 9	-	-	-	-	11 (6)	5.6	-	-	-
Buoy 7A	-	-	-	7.5	11 (7)	17 (12)	-	35 (6)	-
Buoy 1	-	-	-	7.6	-	30 (12)	-	1.6	2.2 (6)
G.S. 2	-	-	-	5.6	3 (6)	4 (6)	-	1.3	3.8 (10)
							-	6.6	4.5 (6)
							-	10 (12)	-

\* Measurements made in laboratory

S, M, B = Surface, mid-depth and bottom waters, respectively. Surface encompasses top two meters of the water column. For mid-depth and bottom measurements, actual depth in meters is given in parentheses to the right of the turbidity measurement.

Dash (-) indicates no data taken.

most turbid water at Buoy 11 in the GBEC. Very turbid water (from 85 to 280 NTU) was found in the entrance to the Houston Ship Channel (HSC) near Morgan's Point. This is to be expected since this is an area of intense ship traffic. The data obtained on TCCTB samples show that the surface waters were generally clear at the time of sampling. Moreover, examination of the data in Table IV-2 shows that surface waters tended to be less turbid than mid or bottom waters.

Table IV-3 shows turbidity data in terms of percent transmission for surface waters at GBEC Disposal Site Buoy D on August 27, one day prior to disposal of dredged sediments. With a 10-cm light path, the percent transmission of light ranged from 96 to 98 percent. These data indicate the clarity of the surface waters prior to disposal.

Table IV-3  
Pre-Disposal Turbidity Measurements near Galveston  
Bay Entrance Channel Disposal  
Site Buoy D  
(August 27, 1975)

Depth (m)	Percent Transmission*
1	98
2	98
3	96
4	98
5	98

\*10-cm light path

Temperature, Dissolved Oxygen,  
Salinity and pH

Dredging site water column. Temperature, D.O., salinity and pH of the water column in both the GBEC and GBEC Disposal Site were monitored with the Hydrolab unit. Samples were taken near Buoys 1,3,7,7A, 9 and 11 in the GBEC. Profiles taken near Buoy 1 on April 17, May 7 and June 11, 1975, are shown in Table IV-4. The temperature decreased with depth on the first two dates but showed a slight increase and then a slight decrease with depth on June 11. Salinity increased with depth except for the reading found at 14 meters on May 7; the pH was a constant 8.3.

Table IV-5 summarizes the data from the one profile (April 18) taken near Buoy 3. The data show that temperature and D.O. decreased with depth while salinity increased with depth. The water column near Buoy 7 was also monitored on April 18 (at 9:50). The data are presented in Table IV-6. The temperature decreased with depth down to 10 meters and then increased by  $0.5^{\circ}\text{C}$  at 13 meters. The D.O. increased slightly with depth; there was a 0.4 mg/l difference between surface and bottom waters. Salinity and pH increased with depth.

The Buoy 7A water column was monitored on May 7 at 14:15 (flood tide) and 17:20 (ebb tide), and the resultant data can be found in Table IV-7. The parameters measured on May 7 showed some variability with the tidal cycle. The temperature decreased with depth at both monitoring times. There was an overall temperature increase in the water column when the warmer bay waters ebbed out. On May 7 D.O. decreased with depth, although there was an

Table IV-4  
Water Column Measurements: Galveston  
Bay Entrance Channel near Buoy 1

Date & Time Collected (1975)	Depth (m)	Temp (°C)	D.O. (mg/l)	Salinity (°/oo)	pH
4/17 10:05	1	21.0	9.5	18.0	8.3
	4	19.5	9.5	19.0	8.3
	7	19.5	9.4	24.0	8.3
	10	19.5	8.9	25.0	8.3
	13	19.0	8.5	25.0	8.3
5/7 15:40	1	27.0	7.7	12.2	-
	4	26.0	7.5	13.0	-
	6	25.0	7.5	13.2	-
	8	25.0	7.6	13.5	-
	10	25.0	7.6	13.7	-
	14	25.0	7.7	13.5	-
6/11 13:30	1	26.0	7.6	27.0	-
	4	26.5	7.3	27.7	-
	6	26.5	6.5	27.7	-
	8	26.5	6.1	28.2	-
	10	26.5	4.1	29.0	-
	12	26.0	1.5	30.5	-
	14	26.0	0.4	31.2	-

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Dash (-) indicates no data taken.

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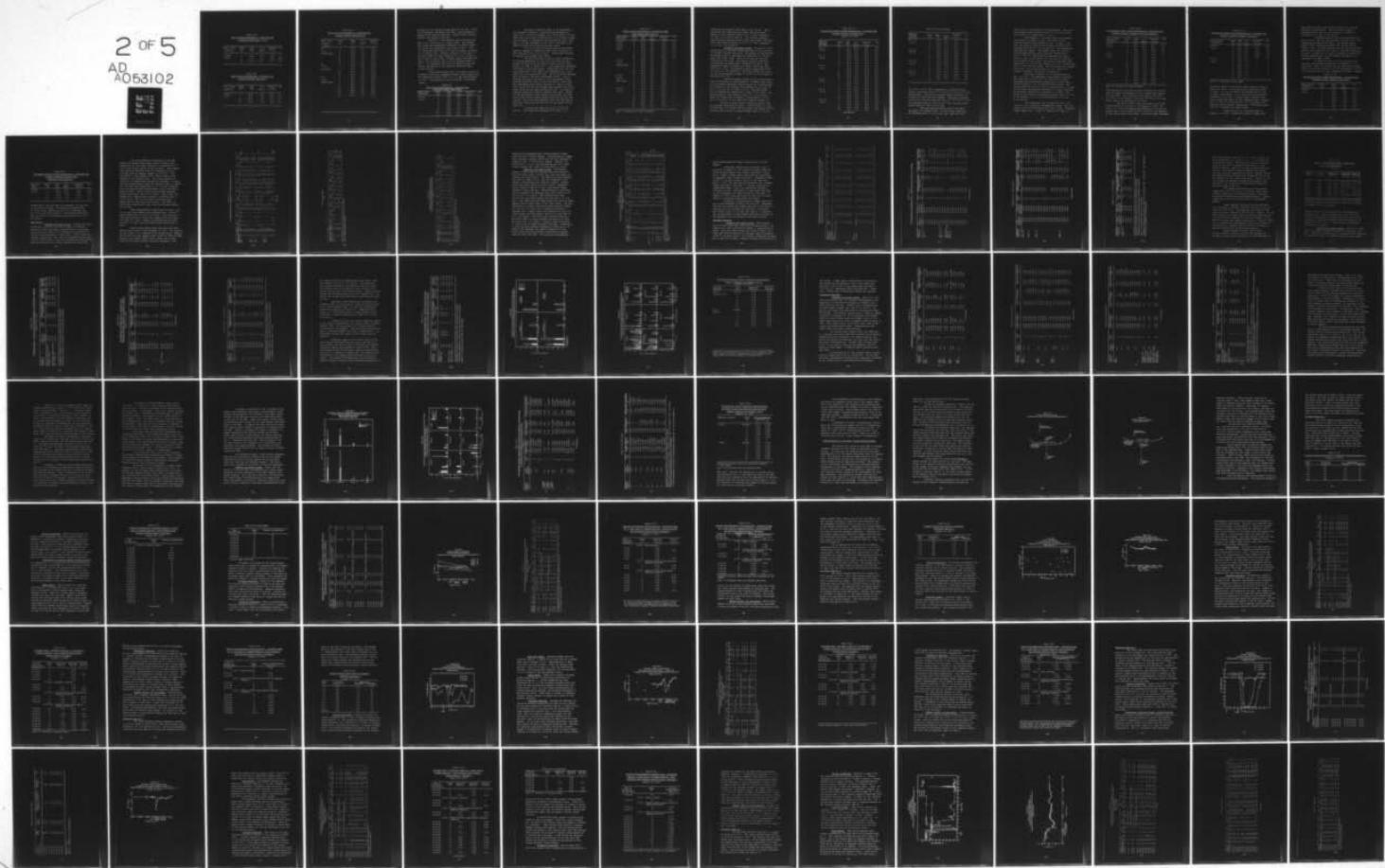


Table IV-5  
Water Column Measurements: Galveston Bay  
Entrance Channel Near Buoy 3

Date & Time Collected	Depth (m)	Temp (°C)	D.O. (mg/l)	Salinity (°/oo)	pH
4/18/75	1	20.0	9.5	18.5	7.5
10:20	5	19.5	9.3	21.0	8.5
	10	19.0	8.9	22.2	8.6

Table IV-6  
Water Column Measurements: Galveston Bay  
Entrance Channel Near Buoy 7

Date & Time Collected	Depth (m)	Temp (°C)	D.O. (mg/l)	Salinity (°/oo)	pH
4/18/75	1	20.0	8.5	18.5	7.3
9:50	5	19.5	8.8	20.0	7.4
	10	18.5	8.9	21.0	8.2
	13	19.0	8.9	21.0	8.4

Table IV-7  
Water Column Measurements: Galveston Bay  
Entrance Channel Near Buoy 7A

Date & Time Collected (1975)	Depth (m)	Temp (°C)	D.O. (mg/l)	Salinity (°/oo)
5/7	1	26.0	7.7	13.0
14:15	4	25.5	7.4	15.5
(Flood tide)	6	25.5	7.3	15.8
	8	25.0	7.2	16.3
	10	25.0	7.1	17.0
	13	24.5	6.8	17.8
5/7	1	27.0	9.3	13.5
17:20	4	26.0	8.5	13.5
(Ebb Tide)	7	25.5	7.6	14.8
	10	25.0	7.3	16.5
	13	25.0	7.1	16.8
6/11	1	26.0	5.8	27.0
11:30	4	26.0	5.6	27.0
(Slack Tide)	6	26.0	5.2	27.7
	8	26.0	4.3	27.7
	10	26.0	4.0	28.2
	12	26.0	3.8	28.2
	14	26.0	3.8	28.2
	16	26.0	3.6	28.2

increase in D.O. during the ebb cycle of the tide. Salinity consistently increased with depth and was higher in samples taken during flood tide. Surface water salinity, however, was higher at ebb tide.

Table IV-7 also presents data collected near Buoy 7A at 11:30 on June 11 (slack tide). The temperature, which was homogeneous throughout the water column, was within the temperature range found on May 7. The D.O. decreased with depth as it had for samples collected on the earlier date. However, surface D.O. on June 11 was much lower (5.8 mg/l compared to 7.7 and 9.3 mg/l on May 7) than it was in May. Salinity again increased with depth but ran higher than it had in readings taken on May 7. The cumulative data for both dates indicate the natural variability of the system at different times of day and year.

Data collected near Buoy 9 at 10:00 on April 12 revealed a relatively homogeneous water column (Table IV-8). The temperature varied 0.5°C, D.O. 0.1 mg/l and salinity 0.8 ‰. No variation in pH was detected in the water column.

Table IV-8  
Water Column Measurements: Galveston Bay  
 Entrance Channel Near Buoy 9

Time & Date Collected	Depth (m)	Temp (°C)	D.O. (mg/l)	Salinity ‰	pH
4/12/75 10:00	1	18.5	9.2	19.2	8.3
	3	18.0	9.2	19.2	8.3
	5	18.0	9.3	19.0	8.3
	7	18.0	9.3	19.5	8.3
	9	18.0	9.3	19.5	8.3
	11	18.0	9.3	19.5	8.3
	13	18.0	9.2	19.5	8.3
	15	18.0	9.2	19.8	8.3

The water column near Buoy 11 was monitored on five separate occasions. The results are presented in Table IV-9. The first readings (at 11:00 on April 12) were taken near the surface and the bottom. No variation between the two depths in temperature and salinity was seen. However, a 0.3 mg/l decrease in D.O. and 0.1 decrease in pH between surface and bottom waters were noted.

At 9:00 on April 18 another profile was taken. Again no changes in temperature were noted, although D.O. did fluctuate from 8.8 to 8.6 mg/l. Salinity did increase noticeably; pH decreased with depth.

The profiles taken on June 11 permit comparison of measured parameters for ebb and flood tides and comparison of these data with those for ebb and flood tides on May 7 at Buoy 7A (Table IV-7). The temperature decreased with depth at both tide states. During ebb tide, the surface waters were  $0.5^{\circ}\text{C}$  higher, but temperature at 4 and 7 meters was lower during ebb tide. The bottom water readings were the same at the other measurement period. The D.O. readings decreased with depth at both measurement times and were apparently lower at ebb tide than at flood tide. The underlying waters showed similar D.O. levels at both times except for the two readings taken nearest the bottom; these were slightly higher during ebb tide. The salinity profiles showed the expected increase with depth. Except for two measurements taken nearest the surface, the flood tide profile showed higher salinity than did the ebb tide profile. This could be explained by the fact that the saline water wedge from the Gulf had not yet pushed the bay water out.

A profile was taken at Buoy 11 at 10:40 on June 11. The temperature decreased  $0.5^{\circ}\text{C}$  from 1 to 4

Table IV- 9  
Water Column Measurements: Galveston Inner

<u>Bar Channel Near Buoy 11</u>					
Date & Time Collected	Depth (m)	Temp (°C)	D.O. (mg/l)	Salinity (°/oo)	pH
4/12/75	1	18.5	9.6	19.5	8.5
11:00	14	18.5	9.3	19.5	8.4
4/18/75	1	21.0	8.8	13.0	8.2
9:00	4	21.0	8.6	15.0	7.6
	7	21.0	8.7	15.5	7.4
	10	21.0	8.6	16.5	7.6
	12	21.0	8.6	16.8	7.5
5/7/75	1	26.5	9.7	8.8	-
13:35	4	26.0	8.1	11.9	-
(Flood Tide)	6	25.5	7.4	13.0	-
	8	25.5	7.1	15.0	-
	10	25.0	6.8	16.0	-
	15	24.5	6.0	19.8	-
5/7/75	1	27.0	9.3	11.5	-
18:00	4	25.5	8.0	12.2	-
(Ebb Tide)	7	25.0	7.2	14.2	-
	10	25.0	7.0	15.8	-
	12	24.5	6.6	16.8	-
6/11/75	1	26.5	6.8	24.0	-
10:40	4	26.0	6.3	26.0	-
	6	26.0	5.0	26.0	-
	8	26.0	4.8	27.0	-
	10	26.0	4.7	27.7	-
	12	26.0	4.7	27.7	-
	14	26.0	4.7	27.0	-
	16	26.0	4.7	27.7	-

Dash (-) indicates no data available.

meters and was constant from there to the bottom. The D.O. decreases with depth were much lower than those noted before at this location (from 6.8 to 4.7 mg/l compared to 9.7 mg/l to 6.0 mg/l on May 7). The salinity readings, which typically increased with depth, were higher this time than those observed before (24.0 to 27.7  $^{\circ}$ /oo, compared to 8.8 to 19.8  $^{\circ}$ /oo on May 7).

Disposal site water column. On April 17, 1975, measurements of the water column were made at ten locations in the GBEC Disposal Site grid. The purpose of taking these measurements was to determine the variability in the disposal site water column. Table IV-10 presents the data collected at that time. The results indicate relatively uniform water characteristics throughout the grid. The temperature range of surface (one meter) waters was from 20.5 $^{\circ}$ C to 21.5 $^{\circ}$ C. The mid-depth region ranged from 19.0 $^{\circ}$ C to 20.5 $^{\circ}$ C, a 1.5 $^{\circ}$ C variation. The bottom waters (one meter off the bottom) showed a range of 18.0 $^{\circ}$ C to 19.5 $^{\circ}$ C, again a variation of 1.5 $^{\circ}$ C.

Dissolved oxygen readings of the surface waters show the influence of photosynthesis. Readings taken later in the afternoon generally showed higher D.O. concentrations. The readings of the surface waters ranged from 9.6 mg/l at 11:20 to a high of 12.8 mg/l at 18:05. Mid-depth water D.O. concentrations ranged from 9.3 mg/l to 12.2 mg/l. The bottom waters at Grid Square 13 had a D.O. of 11.4 mg/l, which was higher than the range of bottom water D.O. (7.4 mg/l to 9.8 mg/l) at all other sites sampled on April 17.

Salinity profiles showed increased salinity with an increased distance from shore. In Grid Squares 1, 2 and 6, which were in a direct line from shore (see Figure III-1), surface water salinity increased seaward from 15.5  $^{\circ}$ /oo to

Table IV-10  
Pre-Disposal Water Column Measurements: Galveston Bay  
Entrance Channel Disposal Site  
 (April 17, 1975)

Sampling Location and Time	Depth (m)	Temp (°C)	D.O. (mg/l)	Salinity (‰)	pH
G.S. 1 16:05	1	21	11.6	15.5	8.5
	4	20.5	12.2	16.4	8.5
	7	19.5	9.8	23.7	8.4
G.S. 2 18:05	1	21.5	12.8	16.4	8.6
	4	20.0	10.9	21.2	8.4
	7	19.5	9.9	23.0	8.4
	10	19.5	8.9	25.0	8.2
G.S. 6 11:40	1	20.5	9.9	17.2	8.4
	4	19.0	9.4	22.8	8.3
	7	19.0	9.3	25.0	8.3
	10	19.0	8.7	27.8	8.2
	13	19.0	8.7	28.0	8.2
G.S. 8 15:35	1	21.0	11.4	16.1	8.5
	4	19.5	9.7	22.0	8.4
	7	19.5	9.7	23.3	8.4
	9	19.5	9.2	24.0	8.3
G.S. 9 17:20	1	21.5	12.0	15.8	8.5
	4	20.5	11.7	19.8	8.5
	7	19.5	9.8	23.7	8.4
	10	19.5	7.8	26.5	8.4
G.S. 13 11:20	1	20.5	9.6	17.8	8.3
	4	19.0	9.6	22.0	8.3
	7	19.0	9.6	22.0	8.3
	10	19.0	8.6	28.0	8.3
	13	19.0	11.4	28.2	8.3

(Continued)

Table IV-10 (Concluded)

<u>Sampling Location and Time</u>	<u>Depth (m)</u>	<u>Temp (°C)</u>	<u>D.O. (mg/l)</u>	<u>Salinity (°/oo)</u>	<u>pH</u>
G.S. 15 13:40	1	20.5	10.5	17.5	8.4
	4	20.0	10.1	18.5	8.4
	7	19.0	9.2	22.2	8.3
	10	19.0	8.3	24.4	8.2
G.S. 16 18:30	1	21.5	12.1	16.8	8.6
	4	20.5	11.8	20.1	8.4
	7	19.5	10.0	22.2	8.4
	10	19.5	8.1	27.0	8.2
G.S. 22 14:15	1	21.0	11.4	17.5	8.4
	4	19.5	10.0	19.0	8.4
	7	19.0	9.4	21.2	8.3
	10	18.0	8.4	24.0	8.2
G.S. 23 18:50	1	21.5	12.5	16.8	8.6
	4	20.0	11.4	20.9	8.4
	7	19.5	10.0	23.0	8.4
	10	19.5	7.4	27.3	8.2

16.4 °/oo, to 17.2 °/oo, respectively, and bottom water salinity increased from 23.7 °/oo to 25.0 °/oo to 28.0 °/oo, respectively. This kind of seaward salinity gradient can be seen for some other grid squares. The overall range of salinity for surface waters was from 15.5 °/oo to 17.8 °/oo, for mid-depth from 16.4 °/oo to 24.8 °/oo, and for bottom waters from 23.7 °/oo to 28.2 °/oo.

There was some variation in pH of the water throughout the disposal area. In the surface waters the pH increased from 8.3 to 8.6 with time, which was most

likely due to the influence of photosynthesis. The pH of the mid-depth waters ranged from 8.3 to 8.5, and in the bottom waters it ranged from 8.2 to 8.4.

Measurements of the water column were made at Grid Square 2 on April 17, May 7 and June 11, 1975. (Limited disposal had occurred in G.S. 2 in May.) The data collected on these dates are shown in Table IV-11. Readings were made at 18:05 on April 17. The temperature decreased with depth. The surface waters were  $21.5^{\circ}\text{C}$ , the mid-depth waters,  $20.0^{\circ}\text{C}$ , and the bottom waters,  $19.5^{\circ}\text{C}$ . The D.O. concentrations decreased with depth from 12.8 mg/l at the surface, to 10.9 mg/l at mid-depth and 8.9 mg/l at the bottom. The salinity increased with depth from  $16.4^{\circ}/\text{o}$  at the surface,  $21.2^{\circ}/\text{o}$  at mid-depth and  $25.0^{\circ}/\text{o}$  off the bottom. The pH readings also changed with depth. The pH values were 8.6, 8.4 and 8.2 at surface, mid-depth and bottom, respectively.

The water column at G.S. 2 was monitored on May 7 at 16:20. The temperature again showed a decrease with depth from  $27.0^{\circ}\text{C}$  to  $25.5$  to  $25.0^{\circ}\text{C}$  for surface, mid-depth and bottom waters, respectively. There was no steady decrease in D.O. as had been seen earlier. The surface water was found to have a concentration of 7.9 mg/l; the mid-depth concentration dropped to 7.6 mg/l, while the bottom water concentration increased to 7.7 mg/l. The salinity data showed an increase with depth, from  $12.3^{\circ}/\text{o}$  at the surface to  $13.5^{\circ}/\text{o}$  at mid-depth to  $14.5^{\circ}/\text{o}$  at the bottom.

The temperature data collected in G.S. 2 on June 11 at 14:15 indicate a homogeneous system. The temperature was  $26.0^{\circ}\text{C}$  throughout the water column. Dissolved oxygen ranged from 7.3 mg/l at surface to 6.6 mg/l at

Table IV-11

Pre-Disposal Water Column Measurements: Galveston Bay  
Entrance Channel Disposal Site Grid Square 2

Date and Time Collected	Depth (m)	Temp (°C)	D.O. (mg/l)	Salinity (‰)	pH
4/17/75 18:05	1	21.5	12.8	16.4	8.6
	4	20.0	10.9	21.2	8.4
	7	19.5	9.9	23.0	8.4
	10	19.5	8.9	25.0	8.2
5/7/75 16:20	1	27.0	7.9	12.3	-
	4	26.0	7.6	12.8	-
	6	25.5	7.6	13.5	-
	8	25.0	7.7	14.0	-
	10	25.0	7.6	14.3	-
	14	25.0	7.7	14.5	-
6/11/75 14:15	1	26.0	7.3	26.0	-
	4	26.0	7.1	26.0	-
	6	26.0	6.6	26.0	-
	8	26.0	6.1	27.0	-
	10	26.0	6.0	27.8	-
	12	26.0	6.0	27.8	-

Dash (-) indicates no data available.

mid-depth and 6.0 mg/l near bottom. Salinity data did not show the degree of homogeneity of the system that temperature had shown. The salinity of the surface water was 26.0 ‰. At mid-depth it was also 26.0 ‰, but in the bottom waters it increased to 27.8 ‰.

The data in Table IV-12 were taken in the water column near Buoy C on April 17 and August 27, 1975. On April 17 at 11:20 the temperature decreased 1.5°C from the surface down to four meters (20.5°C to 19.0°C) and remained at that level down to the bottom. Dissolved oxygen decreased

Table IV-12  
Pre-Disposal Water Column Measurements: Galveston Bay  
Entrance Channel Disposal Site Buoy C

Date and Time Collected	Depth (m)	Temp (°C)	D.O. (mg/l)	Salinity (°/oo)	pH
4/17/75 11:20	1	20.5	9.6	17.8	8.3
	4	19.0	9.6	22.0	8.3
	7	19.0	9.5	24.8	8.3
	10	19.0	8.5	28.0	8.3
	13	19.0	11.4	28.2	8.3
8/27/75 16:00	1	29.0	8.2	-	-
	3	29.0	7.9	-	-
	5	29.0	7.9	-	-
	7	28.5	7.6	-	-
	9	28.5	7.7	-	-
	11	28.5	7.3	-	-
	13	28.5	7.3	-	-
	14	28.5	7.1	-	-

Dash (-) indicates no data taken.

with depth except in the bottom waters, where a sharp increase was noted. The surface water concentration was 9.6 mg/l. At 7 and 10 meters the readings were 9.5 and 8.5 mg/l, respectively. At 11 meters the concentration increased to 11.4 mg/l. Salinity again increased with depth as had been noted at other sampling sites. Salinity was 17.8 °/oo, 24.8 °/oo and 28.2 °/oo in surface, mid-depth and bottom waters, respectively. The pH was a constant 8.3 throughout the water column.

Temperature and D.O. were monitored on August 27 at 16:00. Temperature showed a slight drop

with depth ( $29.0^{\circ}\text{C}$  at the surface and  $28.5^{\circ}\text{C}$  in the mid-depth and bottom waters). The D.O. profile showed a decrease from  $8.2 \text{ mg/l}$  at the surface to  $7.6 \text{ mg/l}$  at mid-depth to  $7.1 \text{ mg/l}$  at the bottom.

The water column at Buoy D was measured that day at 15:00. The data are presented in Table IV-13. The temperature decreased with depth. The surface waters showed  $29.0^{\circ}\text{C}$ , mid-depth waters  $28.5^{\circ}\text{C}$  and the bottom waters  $27.5^{\circ}\text{C}$ . The data indicate that the system was homogeneous with respect to D.O. and pH. Dissolved oxygen was  $8.0 \text{ mg/l}$ ,  $7.9 \text{ mg/l}$  and  $7.8 \text{ mg/l}$  at surface, mid-depth and bottom, respectively. The pH remained constant at 8.3 throughout the water column.

On April 17, 1975, at 13:40, the only pre-disposal water column measurements in Reference G.S. 15 were made. Table IV-14 shows that the temperature ranged from  $20.5^{\circ}\text{C}$  at the surface to  $20.0^{\circ}\text{C}$  at mid-depth to  $19.0^{\circ}\text{C}$  at the bottom. The D.O. also decreased with depth. Surface

Table IV-13  
Pre-Disposal Water Column Measurements: Galveston Bay  
Entrance Channel Disposal Site Buoy D

Date and Time Collected	Depth (m)	Temp ( $^{\circ}\text{C}$ )	D.O. (mg/l)	pH
8/27/75	2	29.0	8.0	8.3
15:00	3	29.0	7.9	8.3
	5	29.0	7.9	8.3
	7	28.5	7.9	8.3
	9	28.5	7.8	8.3
	11	27.5	7.8	8.3
	13	27.5	7.9	8.3
	15	27.5	7.8	8.3

Table IV-14  
Pre-Disposal Water Column Measurements: Galveston Bay  
Entrance Channel Disposal Site  
Reference Grid Square 15

Date and Time	Depth (m)	Temp (°C)	D.O. (mg/l)	Salinity (o/oo)	pH
4/17/75	1	20.5	10.5	17.5	8.4
13:40	4	20.0	10.1	18.5	8.4
	7	19.0	9.2	22.2	8.3
	10	19.0	8.3	24.4	8.2

concentration was 10.5 mg/l, at mid-depth 10.1 mg/l and at the bottom 8.3 mg/l. The salinity increased from 17.5 o/oo at the surface to 18.5 o/oo at mid-depth and 24.4 o/oo in the bottom waters. The pH varied with depth also; it was 8.4 at the surface and mid-depth and 8.2 at the bottom.

#### Heavy Metals

Dredging site water column. Sampling was done during April, May and June 1975 in order to establish background trace heavy metal concentrations in the dredging and disposal areas and to determine the variability of the metal concentrations in these areas. Water column and sediment samples were taken from the dredging sites and analyzed for heavy metals. The sites included the GBEC (Entrance Channel and Inner and Outer Bar Channels) and the TCCTB.

The data obtained from analysis of the GBEC waters for soluble heavy metals appear in Table IV-15. Examination of these data reveals low concentrations of trace heavy metals typical of marine waters. Many samples were below the detection limit for manganese ( $5 \mu\text{g/l}$ ), although soluble manganese ranged up to  $41 \mu\text{g/l}$ . Concentrations in May changed little, while those in June appeared to be slightly lower. Only seven samples collected in the spring were analyzed for chromium. Of these, four had concentrations below the detection limit ( $<2 \mu\text{g/l}$ ), and the other three ranged from  $2.3$  to  $4.7 \mu\text{g/l}$  chromium. Only two samples showed cadmium above  $2 \mu\text{g/l}$ , the higher being  $3.8 \mu\text{g/l}$ . Nickel levels varied without apparent pattern from under  $1 \mu\text{g/l}$  to  $12.1 \mu\text{g/l}$ . Lead values from dredging site samples were observed to fluctuate from  $<1$  to  $29.4 \mu\text{g/l}$ . The  $29.4 \mu\text{g/l}$  seen for the May Buoy 1 sample was the only value over  $20 \mu\text{g/l}$ . Most lead concentrations were below  $10 \mu\text{g/l}$ , with lower values prevailing in June.

Zinc concentrations ranged from less than  $1 \mu\text{g/l}$  to  $17.0 \mu\text{g/l}$  with highest values during April. Levels of copper ranged from  $1.0 \mu\text{g/l}$  to  $6.8 \mu\text{g/l}$ . Iron concentrations were usually low, with many samples below the detection limit of  $5 \mu\text{g/l}$ . However, concentrations did range as high as  $75 \mu\text{g/l}$ , with the higher levels prevailing in April.

Water column samples were taken from the TCCTB surface waters March 28 and September 20, 1975. The sampling was done prior to the dredging of the turning basin. Comparison of data for these samples (Table IV-16) to those for GBEC dredging site samples (Table IV-15), shows that soluble metal concentrations between them were comparable. The

Table IV-15  
Pre-Dredging Soluble Metal Distribution at Galveston Bay Entrance Channel  
( $\mu\text{g/l}$ )

Sampling Location	Date Collected (1975)	Mn		Cr		Cd		Ni		Pb		Zn		Cu		Fe		Hg		
		$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	
Buoy 1	1	5/7	8	0	4.7	0	<0.5	-	<1	-	5.3	0	<1	-	2.3	0	<5	0	0.046	0.045
	12	5/7	13	2	-	1.5	0.5	7.6	2.7	29.4	3.9	6.0	2.2	6.8	5.1	25	7	0.027	0	
	1	6/11	< 5	-	-	1.0	0.1	9.2	0.4	3.3	0.8	1.9	0.4	4.1	0.1	<5	-	0.004	0	
	6	6/11	< 5	-	-	1.0	0.1	9.2	0.4	2.1	0.3	2.3	0.1	4.0	0.3	12	1	0.005	0	
	10	6/11	< 5	-	-	1.3	0.1	8.7	0.4	3.1	0	1.6	0.2	3.4	0.1	<5	1	0.004	0	
Buoy 3	1	4/18	-	-	-	1.7	0.2	-	-	9.0	7.6	12.2	1.9	2.1	0.1	52	0	-	-	
Buoy 7	1	4/18	-	-	-	1.3	0.2	-	-	<1	-	12.5	3.2	2.3	0.4	52	0	0.037	0	
	12	4/18	-	-	-	2.5	1.6	-	-	<1	-	10.4	1.5	2.4	0.1	75	1	0.016	0	
Buoy 7A	1	5/7	5	-	<2	-	<0.5	-	7.8	0	5.0	0.6	3.8	0.1	3.7	0	9	0	0.005	0
	7	5/7	< 5	-	<2	-	0.8	0.1	8.1	0.4	5.0	0	3.8	0	3.7	0	9	0	-	-
	12	5/7	9	0	2.3	0	<0.5	-	<1	-	5.3	0	2.3	0	1.0	0	<5	-	0.040	0.004
	1	6/11	< 5	-	-	3.8	0.1	9.2	0.4	2.5	0.3	3.7	0	4.9	0	<5	-	0.004	0	
	6	6/11	< 5	-	-	1.1	0.6	3.5	0.3	2.1	0.3	1.3	0	3.4	0.4	<5	-	0.004	0	
Buoy 9	11	4/12	-	-	-	0.5	-	-	-	<1	-	7.4	0.6	2.5	0.5	<5	-	0.021	0	
Buoy 11	6	4/12	-	-	-	1.7	0	-	-	14.4	0	12.9	0	3.6	0	<5	-	0.011	0	
	1	4/18	-	-	-	1.0	0.9	-	-	11.3	9.6	17.0	1.1	3.9	0.1	64	0	0.052	0	
	7	4/18	-	-	-	1.1	0.2	-	-	10.8	5.1	15.2	1.9	3.3	0.1	52	0	0.016	0	
	12	4/18	-	-	-	1.2	0.4	-	-	4.6	5.0	10.1	1.1	2.6	0.1	54	8	0.067	0	
	1	5/7	16	0	<2	-	1.3	0	7.9	0	4.7	0	8.5	0	2.3	0	<5	-	0.133	0.021
	6	5/7	9	0	<2	-	<0.5	-	3.2	0	5.3	0	1.9	0	1.5	0	<5	-	0.081	0.004

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(Continued)

Table IV-15 (Concluded)  
( $\mu\text{g/l}$ )

Sampling Location (m)	Date Collected (1975)	<u>Mn</u>		<u>Cr</u>		<u>Cd</u>		<u>Ni</u>		<u>Pb</u>		<u>Zn</u>		<u>Cu</u>		<u>Fe</u>		<u>Hg</u>	
		<u><math>\bar{x}</math></u>	<u>SD</u>																
Buoy 11 7	5/7	4.1	9	2.4	0	0.8	0	12.1	0	5.6	0	11.0	0	1.6	0	<5	0	0.019	0.025
1	6/11	<5	-	-	-	1.2	0.1	8.4	1.4	2.9	1.4	1.7	0.3	4.0	0	<5	-	0.005	0.001
6	6/11	<5	-	-	-	1.0	0.1	10.4	0.7	2.7	0	3.8	0.1	4.5	0.4	7	3	0.005	0
12	6/11	<5	-	-	-	1.2	0.1	9.9	0.7	3.3	0.8	2.7	0.9	3.7	0.1	5	0	0.005	0.001

Mean and standard deviation calculated from duplicate analyses.  
Dash (-) indicates data not available.

Table IV-16  
 Pre-Disposal Soluble Heavy Metal Concentrations:  
Texas City Channel and Turning Basin Surface Waters  
 (ug/l)

Sampling Location	Date Collected	Mn		Cr		Cd		Ni		Pb		Zn		Cu		Fe		Hg		As	
		X	SD	X	SD	X	SD	X	SD	X	SD	X	SD	X	SD	X	SD	X	SD	X	SD
TCC 1	3/28	52	2	11.1	2.5	1.8	0.1	4.1	1.5	3.6	1.2	13.3	0.6	5.4	0	5	3	0.270	0.012	-	-
TCC 2	3/28	5	-	<2	-	<0.5	-	-	-	1.0	-	8.7	-	<1	-	<5	-	0.028	-	-	-
TCC 3	3/28	12	-	<2	-	<0.5	-	-	-	<1	-	19.3	-	1.7	-	<5	-	0.099	-	-	-
TCC 4	9/20	74	8	<2	-	1.1	0	4.9	0.7	7.2	1.1	1.3	0.4	5.7	0.2	5	1	0.007	0	<2	-
TCC 5	9/20	51	8	<2	-	1.4	0.1	4.8	0	9.7	0.5	3.0	0.6	5.4	0.3	5	0	0.007	0	<2	-
TCC 6	9/20	68	0	<2	-	0.8	0.2	5.1	0.4	15.0	1.0	1.3	0.3	5.7	0.5	10	3	0.003	0	<2	-

Mean and standard deviation calculated from duplicate analyses.

Dash (-) indicates data not available.

All samples taken at 1-m depth.

exception was manganese, which showed generally higher concentrations in TCCTB samples. Concentrations of manganese, chromium, cadmium, nickel and iron were apparently similar at the six TCCTB sites sampled. However, the TCCTB Sites 1, 2 and 3 did show mercury and zinc levels slightly higher than those of TCCTB Sites 4, 5 and 6.

Disposal site water column. Pre-disposal samples of water from the disposal area were collected from the water column in April, May, June and August and analyzed for heavy metals. The results of these analyses are listed in Table IV-17. With the exception of two samples, chromium was below detection limits. Cadmium levels were never found to be over 2  $\mu\text{g/l}$ . Manganese values reached a high of 39  $\mu\text{g/l}$ , with higher values apparent in April and May. Concentrations of lead fluctuated throughout the sampling area, with a high of 33.2  $\mu\text{g/l}$  in G.S. 23 in April. Wide variation was also noticed with zinc, which ranged from less than 1 to 27.6  $\mu\text{g/l}$ . Once again many more high values were found in April samples than in those taken in the other months. The concentrations of nickel varied from below detection limits of 1  $\mu\text{g/l}$  to 12.1  $\mu\text{g/l}$ , with no apparent relation to sampling date. Copper levels were generally in the 2 to 5  $\mu\text{g/l}$  range, with the highest value of 8.8  $\mu\text{g/l}$  seen at G.S. 16 in April. Iron levels were usually below the detection limit of 5  $\mu\text{g/l}$ ; however one value of 34  $\mu\text{g/l}$  was found (G.S. 2 in April). Mercury levels were below 0.1  $\mu\text{g/l}$ , with one sample showing 0.081  $\mu\text{g/l}$ . Comparison of data for these samples, presented in Table IV-17, to those of the dredging site samples (Tables IV-15 and IV-16) shows that soluble metal concentrations between them were about the same. The exception was manganese.

Table IV-17  
Pre-Disposal Soluble Heavy Metal Concentrations: Galveston Bay  
Entrance Channel Disposal Site  
( $\mu\text{g/l}$ )

Sampling Location (G.S.)	Depth Collected (m)	Date Collected (1975)	Mn		Cr		Cd		Ni		Pb		Zn		Cu		Fe		Hg		
			X	SD	X	SD	X	SD	X	SD	X	SD	X	SD	X	SD	X	SD	X	SD	
G.S. 1	2	4/17	-	-	-	-	1.3	0	6.2	0	6.9	0	17.2	0	5.5	0	< 5	-	< 0.001	-	
	9	4/17	25	5	<2	-	1.4	0	4.3	0	6.7	0	22.5	0	2.7	0	< 5	-	0.002		
G.S. 2	9	4/17	9	1	<2	-	1.2	0.8	6.2	3.9	29.4	3.9	10.0	2.7	2.7	4.1	23	3	0.018	-	
	2	5/6	9	0	4.6	0	<0.5	-	<1	-	5.3	0	<1	-	3.6	0	< 5	0	-	-	
	2	5/6	8	0	<2	-	1.7	0.4	9.0	0.8	29.0	1.5	10.4	0.6	4.8	1.1	34	22	< 0.001	-	
	1	5/7	7	0	<2	-	0.6	0	6.2	0	<1	-	7.3	0	3.7	0	< 5	-	-	-	
	6	5/7	<5	-	-	-	0.8	0.7	8.1	4.9	23.4	2.0	24.4	22.6	2.6	1.9	18	12	< 0.001	-	
	1	6/11	<5	-	-	-	1.2	0.1	9.2	0.4	3.3	0.3	2.8	1.2	4.3	0.4	< 5	1	0.004	0	
	6	6/11	<5	-	-	-	1.0	0.1	10.9	1.3	2.7	0	2.8	0.7	4.6	0.1	< 5	-	0.004	0	
	12	6/11	<5	-	-	-	1.2	0.1	9.2	0.4	3.7	0.3	3.0	1.1	2.8	0.1	< 5	-	0.004	0	
G.S. 8	2	4/17	16	4	<2	-	1.4	0.4	7.1	1.4	27.6	1.0	5.2	0.9	2.9	0.7	17	10	0.036	0	
	9	4/17	<5	-	2.7	0	<0.5	-	<1	-	<1	-	<1	-	2.0	0	< 5	-	0.005	0.001	
G.S. 9	S*	4/17	22	7	<2	-	0.8	0	<1	-	6.1	0	19.3	0	2.6	0	< 5	-	0.023	0	
	9	4/17	39	2	<2	-	1.1	0	12.1	0	6.7	0	6.3	0	5.2	0	5	0	< 0.081	0.090	
	6.S. 13	4/17	23	6	<2	-	1.4	0	7.6	0	6.9	0	27.6	0	3.0	0	< 5	-	< 0.001	-	
	6.S. 16	10	4/17	<5	-	<2	-	1.1	0	6.4	0	26.6	0	20.3	7.2	8.8	5.6	12	0	0.027	0
	G.S. 22	2	4/17	9	1	<2	-	1.1	0	4.5	0.8	26.7	0.3	8.8	5.6	1.1	0.9	24	1	0.027	0
	G.S. 23	2	4/17	7	1	<2	-	1.1	0.4	7.1	0.4	33.2	9.2	3.9	1.9	<1	-	18	0	< 0.001	-
	10	4/17	<5	-	<2	-	0.7	0.2	1.3	0.4	24.5	2.6	20.9	29.2	2.6	0.4	9	5	< 0.001	-	

Mean and standard deviation calculated from duplicate analyses.

Dash (-) indicates data not available.

\*Surface

which showed generally higher concentration in TCCTB samples.

Additional samples from near Buoys C and D collected on August 27, 1975 (before disposal) were analyzed for heavy metals; the results are shown in Table IV-18. Higher soluble metal concentrations, especially of manganese, were noticed near Buoy C. Manganese ranged from 13 to 24  $\mu\text{g/l}$  at Buoy D and 15 to 307  $\mu\text{g/l}$  near Buoy C. Also, zinc and lead concentrations were slightly higher near Buoy C than Buoy D. Arsenic, chromium and cadmium were below 2  $\mu\text{g/l}$ , and mercury was generally 0.01  $\mu\text{g/l}$  or less. The levels of copper were less than 10  $\mu\text{g/l}$  throughout the water columns at both sites. A range of <5 to 43  $\mu\text{g/l}$  was found for iron, with an indication of increased concentration with depth.

Generally, concentrations in August were similar to those measured in April, May and June. Manganese, lead and zinc levels were higher near Buoy C than Buoy D. This may be due to location of the buoys, since Buoy D was located closer to the open Gulf waters. In general, the concentrations of heavy metals were about the same in the dredging sites and disposal sites water columns.

#### Nitrogen Compounds

Dredging site water column. Water samples from the GBEC (Inner Bar, Outer Bar, Entrance Channel; see Figure III-1) were analyzed for organic N, ammonium and nitrate. Data from these analyses are shown in Table IV-19. These data show variability in nitrogen compound concentrations of the water found in the channels connecting Galveston Bay to the Gulf of Mexico. Organic nitrogen concentrations in

Table IV-18  
Pre-Disposal Soluble Heavy Metal Concentrations: Galveston Bay  
Entrance Channel Disposal Site Buoys C and D, August 27, 1975

Sampling Location and Time	Depth (m)	Mn	Cr	Cd	Ni	Pb	Zn	Cu	Fe	Hg	As
<b>Buoy C (16:00-16:30)</b>											
3	1.81	<2	1.5	10.0	6.5	11.4	4.8	22	0.01	<2	
6	3.07	<2	1.1	6.3	7.0	17.0	7.7	43	0.01	<2	
9	2.5	<2	1.1	12.1	5.5	11.3	4.4	14	0.01	<2	
12	1.53	<2	1.8	6.3	4.7	16.4	4.4	17	0.01	<2	
15	1.23	<2	0.6	11.8	4.1	26.7	4.0	20	0.01	<2	
18	2.47	<2	1.0	16.6	10.9	45.9	3.2	24	0.001	<2	
<b>Buoy D (15:00)</b>											
3	1.3	<2	0.8	2.6	5.9	5.1	3.5	<5	0.01	<2	
6	2.1	<2	1.4	5.0	5.3	26.1	6.0	9	0.01	<2	
9	2.2	<2	0.8	2.6	7.6	7.3	4.8	15	0.01	<2	
12	1.6	<2	0.9	1.4	1.9	8.2	17.6	7.7	17	0.01	<2
15	2.4	<2	0.9	7.5	5.3	11.6	5.2	7	0.01	<2	
18	2.0	<2	1.2	17.4	7.0	17.5	5.6	26	0.001	<2	

Table IV-19  
Pre-Disposal Nitrogen Data: Galveston Bay Entrance Channel

Sampling Location	Date Collected (1975)	Time of Collection (hr:min)	Depth (m)	Organic Nitrogen*		Ammonium**		Nitrate* (mg N/l)	
				$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Buoy 1	4/17	08:00	2	0.15	0.05	0.05	0.01	0.14	0
	5/07	15:40	1	0.28	0.05	0.04	0.01	-	-
	5/07	15:40	12	0.26	0.02	0.02	0	0.37	0.02
6/11	13:30	1	0.28	0	0.01	0	0.04	0	
6/11	13:30	6	0.20	0	0.01	0	0.07	0.01	
6/11	13:30	10	0.16	0.03	< 0.01	0	0.06	0	
900 m SW of Buoy 5	6/11	14:35	1	0.16	0	0.01	0	0.04	0
100 m up-channel from Buoy 7	4/18	14:35	6	0.24	0	0.01	0	0.04	0
Buoy 7A	5/07	09:50	1	-	-	0.03	0	0.05	0
	5/07	14:15	12	-	-	0.04	0.01	0.05	0
	5/07	14:15	1	0.26	0	0.06	0	0.32	0.02
	5/07	14:15	6	3.99	0.08	0.01	0	0.30	0.01
	5/07	14:15	12	0.23	0	0.01	0	-	-
	5/07	17:20	1	0.16	0.04	0.04	0	0.42	0
	5/07	17:20	7	0.22	0	0.06	0	0.33	0.01
6/11	11:30	1	0.21	0.03	< 0.01	0	0.07	0.01	
6/11	11:30	1	0.20	0	0.02	0	0.04	0	

(Continued)

Table IV-19 (Continued)

Sampling Location	Date Collected (1975)	Time of Collection (hr:min)	Depth (m)	Organic Nitrogen*		Ammonium**		Nitrate*	
				X	SD	X	SD	X	SD
Buoy 7A	6/11	11:40	6	0.36	0.03	0.02	0	0.06	0.01
	6/11	11:40	12	0.28	0	0.01	0	0.12	0.02
Buoy 9	4/12	10:00	1	0.86	0.05	0.10	0.01	0.16	0.01
	4/12	10:00	11	0.35	0.02	0.09	0	0.13	0
Buoy 11	4/12	10:00	11	0.42	0.01	0.08	0	0.12	0.01
	4/12	11:00	6	0.38	0.02	0.06	0.01	0.12	0.01
4/18	09:00	1	0.56	0.05	0.04	0.01	0.05	0	
	09:00	7	0.43	0.04	0.02	0	0.05	0	
4/18	09:00	12	0.51	0.02	0.03	0	0.05	0	
	09:00	13	-	-	0.08	0.01	0.08	0.01	
4/18	17:30	1	-	-	0.08	0.01	0.05	0.01	
	13:35	1	0.35	0.05	0.25	0.03	0.21	0.01	
5/07	13:35	6	0.27	0.04	0.13	0.03	-	-	
	13:35	12	0.42	0.08	0.06	0	-	-	
Buoy 11	5/07	18:00	1	0.40	0.02	0.12	0.01	0.22	0.01
	5/07	18:00	7	0.27	0.01	0.09	0	0.29	0.01
6/11	10:40	1	0.36	0	< 0.01	0	0.03	0	
	10:40	6	0.28	0.03	0.03	0	0.09	0.01	

(Continued)

Table IV-19 (Concluded)

Sampling Location	Date Collected (1975)	Time of Collection (hr:min)	Depth (m)	Organic Nitrogen*		Ammonium**		Nitrate*	
				$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Buoy 11	6/11	10:40	12	0.40		0.02	0.06	0.01	0.12
	6/11	15:35	1	0.44		0	0.15	0.01	0.09
	6/11	15:35	6	0.28		0	0.04	0	0.08
	6/11	15:35	11	0.32		0	0.04	0	0.05

\*Standard deviation calculated from triplicate analyses.

\*\*Standard deviation calculated from duplicate analyses.

Dash (-) indicates data not available.

Standard deviations where at least one replicate was less than the detection limit are necessarily approximate.

this region varied from 0.15 to 0.86 mg N/l, except for one concentration of 3.99 mg N/l which was probably due to analytical error. Concentrations tended to decrease from the GBEC Buoy 11 seawards toward Buoy 1 in the Entrance Channel. Where the Entrance Channel mixes with the Gulf, the organic nitrogen, ammonium and nitrate concentrations all decreased with depth, possibly because the higher nitrogen-content water transported out of the bay overlies the more saline Gulf water. Three- to four-fold changes in nitrogen compound concentrations were observed at one station on different days and even at different times on one day.

The ammonium concentrations in the channel ranged from 0.01 to 0.25 mg N/l, with the lower concentrations generally in the Entrance Channel. Ammonium concentration patterns were extremely variable. Nitrate ranged from <0.05 to 0.42 mg N/l with no discernible pattern.

Water samples collected from the TCCTB were also analyzed for nitrogen compounds; the results are presented in Table IV-20. High ammonium and organic N concentrations were observed in the TCC Site 1 sample. For the other samples, the higher range of ammonium concentration (0.22 mg N/l) was comparable to that of the GBEC. In the other five Texas City samples there was a 0.10 mg N/l variation in ammonium and considerable variation in organic N concentrations. However, there was little difference in nitrate concentrations between these samples.

Water samples collected from the HSC (Morgan's Point) on April 18, 1975, were analyzed for nitrogen to obtain some information on concentrations of

Table IV-20  
Pre-Disposal Nitrogen Data: Texas City  
Channel Turning Basin  
 (mg N/l)

Sampling Location	Date Collected	Organic N*		Ammonium**		Nitrate*	
		$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
TCC 1	3/28	5.0	1.0	0.59	0.04	0.08	0.01
TCC 2	3/28	0.25	0.02	0.15	0.01	0.11	0.01
TCC 3	3/28	0.30	0.21	0.22	0.01	0.11	0
TCC 4	9/20	0.84	0.30	0.12	0	0.10	0.01
TCC 5	9/20	0.79	0.22	0.12	0	0.11	0.01
TCC 6	9/20	0.15	0.09	0.12	0.01	0.04	0.01

\*Standard deviation calculated from triplicate analyses.

\*\*Standard deviation calculated from duplicate analyses.

All samples taken at 1-m depth.

material likely to be transported to the dredging and disposal areas. These concentrations, shown in Table IV-21, were considerably higher than those found in the dredging and disposal site areas (with the exception of organic N at TCC Site 1). There was no clear pattern with respect to depth.

Disposal site water column. Table IV-22 shows data for nitrogen compound analyses in the disposal site grid. Ammonium concentrations in this region were comparable to those in the GBEC. No definite space or time pattern

Table IV-21  
 Nitrogen Data: Houston Ship Channel-Morgan's Point Water Samples  
 (April 18, 1975)

Sampling Location	Time of Collection (hr:min)	Depth (m)	Organic Nitrogen*		Ammonium**		Nitrate*	
			$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Houston Ship Channel-Morgan's Point	13:40	2	0.58		0.17	0.66	0.01	0.35
	13:40	12	1.06		0.04	0.66	0	0.73
900 meters below Dupont	14:05	2	0.58		0.09	0.38	0.01	1.07
near Buoy 100	14:05	12	0.58		0.04	0.74	0	0.58

\*Standard deviation calculated from triplicate analyses.

\*\*Standard deviation calculated from duplicate analyses.

Table IV-22  
Pre-Disposal Nitrogen Data: Galveston Bay  
Entrance Channel Disposal Site Water Samples  
(April 17, 1975)

Sampling Location G.S.	Time of Collection (hr:min)	Depth (m)	Organic Nitrogen*		Ammonium**		Nitrate*	
			$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
1	16:05	2	0.18	0.01	0.14	0.01	0.19	0.01
	16:05	9	0.16	0	0.04	0	0.10	0.01
2	18:05	2	0.32	0.02	0.20	0.02	0.15	0.01
	18:05	9	0.06	0.01	0.05	0.01	0.08	0
4	14:15	1	0.20	0.03	0.03	0	0.06	0
	14:15 +	6	0.20	0	0.01	0	0.10	0
5	14:15 +	12	0.28	0	0.06	0.01	0.04	0
	11:50 +	2	0.17	0.04	0.03	0	0.19	0.01
6	11:50	13	0.24	0.01	0.04	0.01	0.14	0.03
	-							
7	N.E. corner	09:00	2	0.20	0.04	0.04	0	0.14
		15:35	2	0.11	0.03	0.05	0.01	0.21
8		15:35	9	0.16	0.00	0.04	0	0.11
		17:20	0	0.31	0.08	0.21	0	0.16
9		17:20	9	0.10	0	0.06	0	0.60
								0

(Continued)

Table IV-22 (Concluded)

Sampling Location G.S.	Time of Collection (hr:min)	Depth (m)	Organic Nitrogen*		Ammonium**		Nitrate*	
			$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
13	11:20	2	0.23	0	0.09	0	0.14	0
	11:20	2	0.19	0	0.09	0	0.15	0
	11:20	1.3	0.06	0.05	0.06	0.01	0.10	0.01
15	13:40	2	0.48	0.04	0.16	0	0.16	0.04
	13:40	9	0.20	0	0.08	0	0.16	0.01
	18:30	2	0.20	0.02	0.16	0	0.14	0.01
16	18:30	9.5	0.25	0	0.03	0	0.20	0.02
	14:15	2	0.14	0.05	0.06	0.01	0.26	0.01
	14:15	9	0.25	0.04	0.07	0	0.15	0.01
23	18:50	2	0.28	0	0.04	0	0.19	0.01
	18:50	10	0.24	0.02	0.12	0	0.22	0.01

\*Standard deviation calculated from triplicate analyses.

\*\*Standard deviation calculated from duplicate analyses.

+ Samples collected June 11, 1975.

for organic N could be discerned from these data. Ammonium ranged from 0.01 to 0.21 mg N/l. Concentrations were generally higher in the surface waters and toward the northern side of the disposal area, possibly indicating some influence from Galveston Bay. Surface nitrate concentrations were similar across the disposal area. No pattern for surface and bottom water concentrations could be seen.

Additional water samples were collected from different parts of Grid Square 2, which had been selected as the first disposal area. The data for nitrogen compounds are presented in Table IV-23. Ammonium ranged from 0.04 to 0.08 mg N/l, with no clear pattern in concentration. Nitrate concentrations ranged from 0.14 to 0.40 mg N/l.

Figures IV-1 and IV-2 compare ammonium, organic N and nitrate concentrations from the HSC, GBEC, and GBEC Disposal Site. As can be seen, HSC nitrogen compound concentrations were highest. Ammonium concentrations were found to decrease seaward from Buoy 11 toward Buoy 1. No discernible pattern for organic N and nitrate could be observed.

Ammonium, organic N and nitrate data for the water samples collected from near Buoy C and Buoy D in the disposal site grid on August 27 (before the disposal operations began) are presented in Table IV-24. These are background data for nitrogen compound concentrations just prior to disposal at these sites. The ammonium concentrations of all samples were found to be below 0.05 mg N/l. The organic N concentrations did not show any specific pattern, probably indicating some variability in

Table IV-23  
Pre-Disposal Nitrogen Data: Galveston Bay Entrance  
Channel Disposal Site Grid Square 2 Water Samples

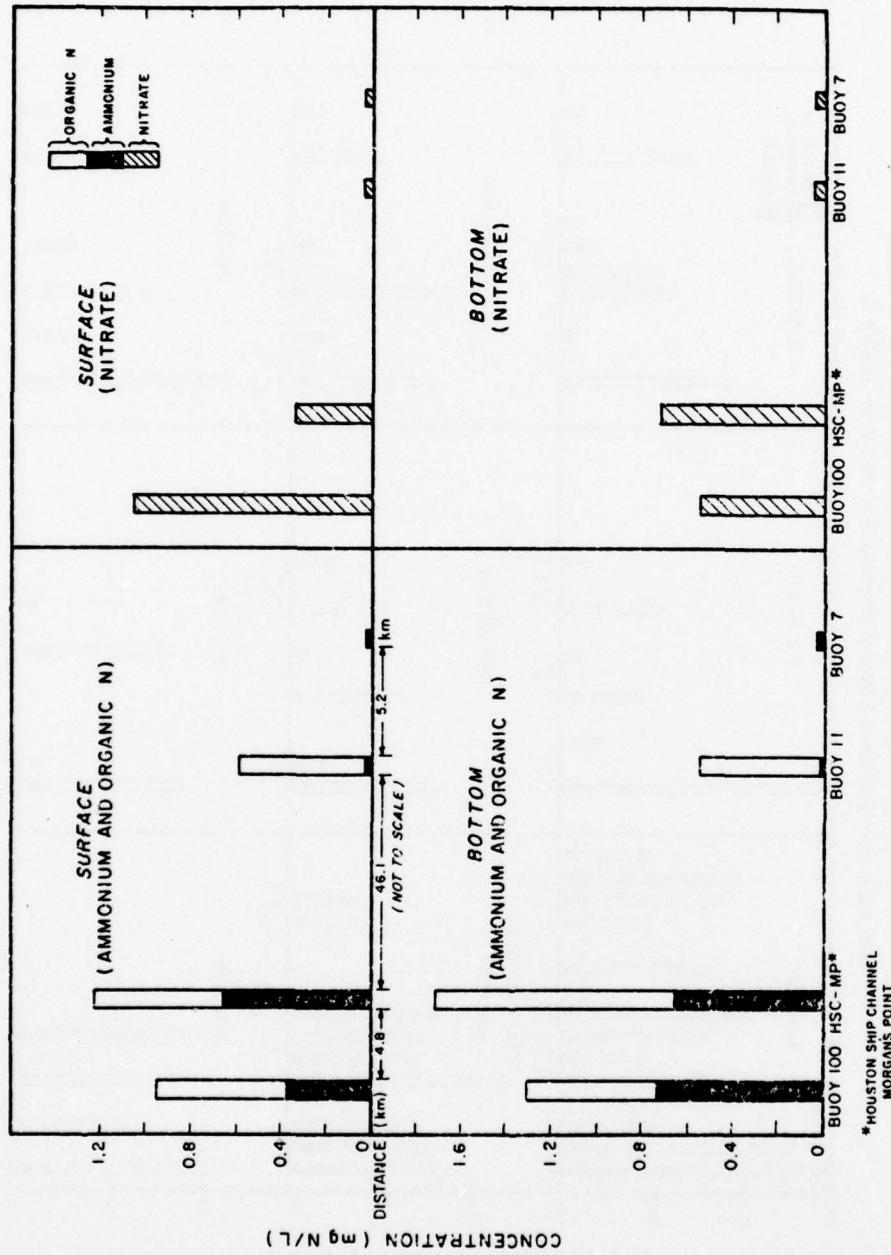
Sampling Location	Date Collected (1975)	Time of Collection (hr:min)	Depth (m)	Organic Nitrogen*		Ammonium**		Nitrate*	
				$\bar{x}$ (mg N/l)	SD	$\bar{x}$ (mg N/l)	SD	$\bar{x}$ (mg N/l)	SD
Midpoint of SW-NW line	5/7	16:20	1	0.16	0.04	0.04	0	0.40	0.02
	5/7	16:20	1	0.28	0	0.08	0	0.20	0.01
5/7	16:20	6	0.16	0		0.04	0	0.14	0.02
East Corner	5/6	-	2	-	-	0.08	0.01	0.37	0.01
North Corner	5/6	-	2	-	-	0.07	0	0.39	0.01

\*Standard deviation calculated from triplicate analyses.

\*\*Standard deviation calculated from duplicate analyses.

Dash (-) indicates data were not available.

**Figure IV-1**  
**Comparison of ammonium, organic N and nitrate concentrations from  
 Houston Ship Channel to Galveston Bay Entrance Channel on April 18, 1975**



\*HOUSTON SHIP CHANNEL  
 MORGAN'S POINT

**Figure IV-2**  
**Comparison of ammonium, organic N and nitrate concentrations through  
 Galveston Bay Entrance Channel Disposal Site and Grid Square 2**

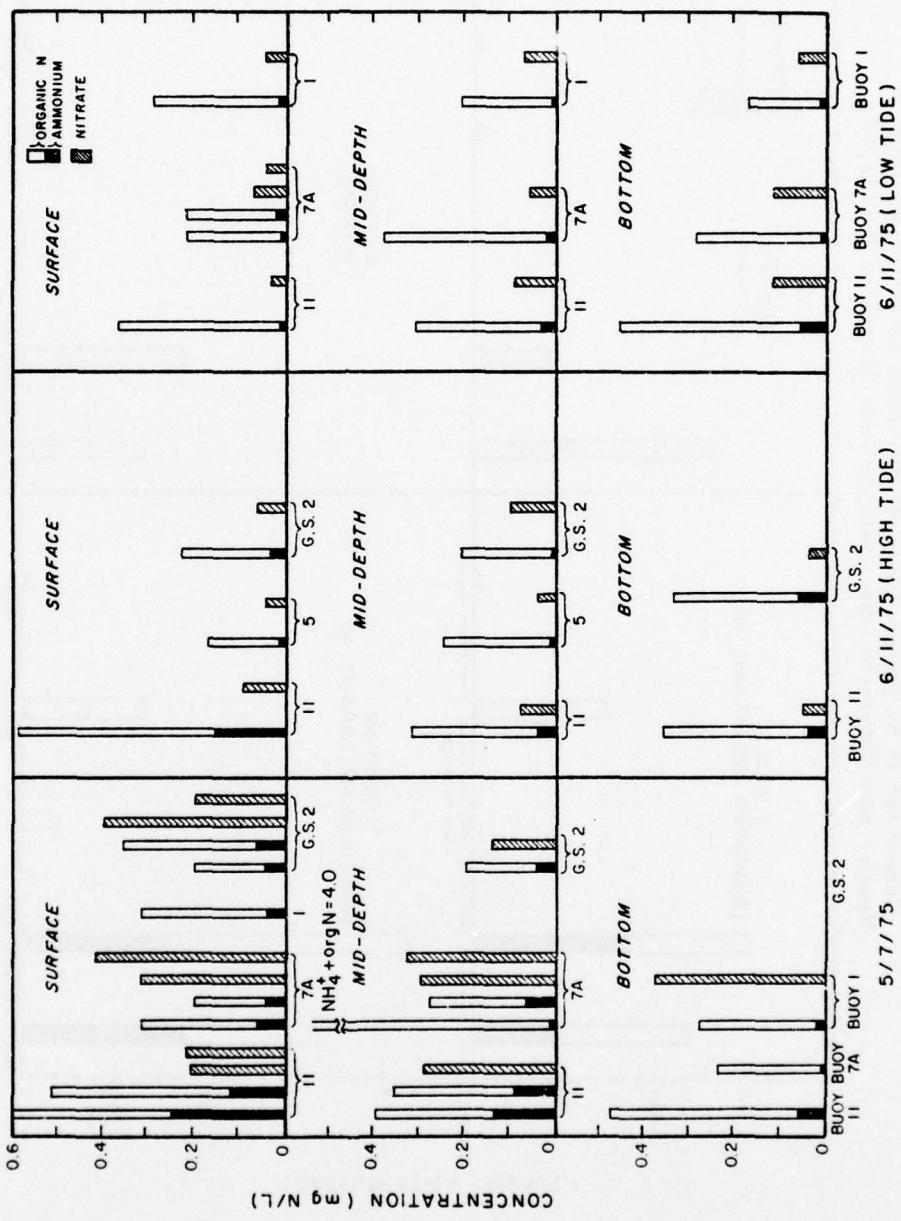


Table IV-24  
Pre-Disposal Nitrate Data: Galveston Bay Entrance  
Channel Disposal Site Buoys C and D  
(August 27, 1975)

Sampling Location	Depth (m)	Organic N*	Nitrate (mg N/l)
Buoy C (16:00-16:30)	Surface	0.39	0.09
	3	0.31	0.08
	6	0.31	0.09
	9	0.31	2.16
	12	0.35	0.07
	15	0.27	0.12
	18	0.27	0.12
Buoy D (15:00)	Surface	0.27	0.12
	3	0.31	1.56
	6	0.31	0.20
	9	0.27	0.08
	12	0.27	0.08
	15	0.23	0.10
	18	0.31	0.11

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\*Ammonium concentrations were <0.05 for all samples; therefore, organic nitrogen concentrations were determined by subtracting 0.05 from Kjeldahl N concentrations.

the system. A high nitrate concentration (1.56 mg N/l) was observed in the samples at the 3 meter depth from near Buoy D and at the 9 meter depth from near Buoy C (2.16 mg N/l), suggesting sample contamination. Otherwise, a fairly even concentration pattern was observed.

#### Phosphorus Compounds

Dredging site water column. Table IV-25 presents pre-disposal data for soluble orthophosphate, total phosphorus and particulate phosphorus in samples from GBEC, TCCTB and the HSC. Soluble ortho P concentrations in TCCTB samples ranged from 0.095 to 0.20 mg P/l. No pattern was evident from the TCCTB to the Galveston Inner Bar Channel. Pre-disposal soluble ortho P levels in samples collected on September 20, 1975 (considered pre-disposal relative to the October Texas City dumps), were 1.5 to 2 times higher than those found in samples collected April 12, 1975. Both soluble ortho P and total P were lower in HSC surface water than bottom water. Concentrations were higher than TCCTB sample concentrations.

For surface water samples taken near GBEC Buoy 11, a pattern was evident when both salinity and phosphorus compound data were available. For surface samples, generally the greater the salinity, the lower both the ortho P and total P concentrations. Surface ortho P ranged from 0.021 to 0.163 mg P/l, and with one exception, was different for each sample. Differing surface salinities were also found.

At mid-depth (6 to 7 m), soluble ortho P concentrations ranged from 0.021 to 0.078 mg P/l. For the samples with corresponding salinity data, significant decreases in the soluble ortho P concentrations were generally

Table IV- 25  
Pre-Disposal Soluble Orthophosphate and Total Phosphorus Concentrations  
in Galveston Study Area (Excluding Disposal Site)

Sampling Location	Date Collected (1975)	Depth (m)	Soluble Ortho P		Total Phosphorus		Particulate Phosphorus	
			$\bar{X}$	SD*	$\bar{X}$	SD*	$\bar{X}$	SD*
GBEC Buoy 1	4/17	2	<0.02	~0**	0.05	0.001	~0.030	~0.001**
	5/7	1	0.040	0.01	0.28	0.05	0.240	0.06
		12	0.020	0.003	0.05	0	0.030	0.003
	6/11	1	0.035	0.001	0.04	0.006	0.005	0.007
		6	0.043	0.003	0.03	0.006	~0 †	0.009
		10	0.023	0.001	<0.02	~0	~0 †	~0.001
GBEC Buoy 3	4/18	1	0.031	0.002	0.03	0.01	~0 †	0.012
GBEC Buoy 5	6/11	1	0.029	0.002	0.02	0.006	~0 †	0.008
		6	0.028	0.004	0.04	0.005	0.012	0.010
GBEC Buoy 7	4/17	2	<0.02	~0.003**	0.05	0.002	~0.030**	~0.005**
	4/18	1	0.034	0.005	0.08	0.01	0.046	0.015
		12	0.031	0.008	0.14	0.02	0.109	0.028
GBEC Buoy 7A	5/7	1	0.109	~0	0.10	0	~0 †	~0 **
		6	0.027	0.003	0.05	0.002	0.023	0.005
		12	<0.02	~0	0.07	0	~0.05	~0 **

†25

(Continued)

Table IV-25 (Continued)

Sampling Location	Date Collected (1975)	Depth (m)	Soluble Ortho P		Total Phosphorus		Particulate Phosphorus	
			$\bar{x}$	SD *	$\bar{x}$	SD *	$\bar{x}$	SD *
GBEC Buoy 7A	5/7	1	0.028	0.002	0.03	0	0.002	0.002
		7	0.083	0.003	0.07	0.01	~0 +	0.013
	6/11	1	0.023	0.001	0.04	0.006	0.017	0.007
		1	0.025	0.001	0.04	0.006	0.015	0.010
		6	0.035	0.002	0.13	0.006	0.095	0.008
		12	0.035	0.005	0.13	0.006	0.095	0.011
GBEC Buoy 9	4/12	1	0.052	0.003	0.035	0.01	~0 +	0.013
		11	0.048	0.002	0.16	0.02	0.112	0.022
		11	0.051	0.006	0.07	0.005	0.019	0.011
	5/8	1	0.034	0.001	0.13	0	0.096	0.001
		6	0.022	0	<0.04	~0**	<0.018	~0**
		12	0.030	0.001	<0.04	~0**	<0.01	~0.001**
GBEC Buoy 11	4/12	6	0.047	0.007	0.06	0	0.013	0.007
	4/18	1	0.093	0.002	0.11	0.005	0.017	0.007
		7	0.078	0.007	0.12	0.002	0.042	0.009
		12	0.030	0.005	0.12	0.01	0.090	0.015
		1	0.029	0.004	0.07	0.001	0.041	0.005
		13	0.044	0.004	0.07	0.006	0.026	0.010
5/7	1	0.130	0.002	0.16	0.004	0.030	0.006	
	6	0.069	0.001	0.06	0	~0 +	0.001	

(Continued)

Table IV- 25 (Continued)

Sampling Location	Date Collected (1975)	Depth (m)	Soluble Ortho P		Total Phosphorus		Particulate Phosphorus	
			$\bar{X}$	SD*	$\bar{X}$	SD*	$\bar{X}$	SD*
GBEC Buoy 11	5/7	1	0.112	0.001	0.13	0	0.018	0.001
		7	0.065	0	0.05	0.006	0+	0.006
5/8	1	0.021	0.001	<0.04	<0**	<0.019	<0.001**	
	6	0.021	0.001	0.05	0	0.029	0.001	
	12	0.029	0.001	<0.04	<0**	<0.011	<0.001**	
6/11	1	0.060	0.002	0.07	0	0.01	0.002	
	6	0.025	0.001	0.09	0.006	0.065	0.007	
	12	0.027	0.001	0.16	0.006	0.133	0.007	
6/11	1	0.163	0.003	0.19	0.006	0.027	0.009	
	6	0.049	0	0.05	0.006	0.001	0.006	
	11	0.039	0.003	0.09	0	0.051	0.003	
Houston Ship Channel-Morgan's Point	4/18	2	0.370	0.003	0.65	0.02	0.280	0.023
Houston Ship Channel-Morgan's Point	4/18	12	0.470	0.006	1.17	0.04	0.700	0.046
Houston Ship Channel 0.5 mi below Dupont, near Buoy 100	4/18	2	0.241	0.001	0.59	0.005	0.349	0.006
		12	0.480	0.006	0.88	0.02	0.400	0.026

(Continued)

Table IV-25 (Concluded)

Sampling Location	Date Collected (1975)	Depth (m)	Soluble Ortho P		Total Phosphorus		Particulate Phosphorus	
			$\bar{x}$	SD*	$\bar{x}$	SD*	$\bar{x}$	SD*
Galveston Channel-off Todd Ship Yards	4/12	3	0.083	0.005	0.10	0.002	0.017	0.007
Galveston Yacht Basin	4/12	3	0.083	0.003	0.08	0.01	0	0.013
TCC 1	4/12	1	0.095	0.02	0.10	0	0.005	0.02
TCC 2	4/12	1	0.110	0.006	0.12	0.01	0.01	0.016
TCC 3	4/12	1	0.105	0.003	0.13	0.01	0.025	0.013
TCC 4	9/20	1	0.172	0	-	-	-	-
TCC 5	9/20	1	0.180	0.003	-	-	-	-
TCC 6	9/20	1	0.200	0.002	-	-	-	-

Dash (-) indicates sample not analyzed.

\*Standard deviation based on triplicate analyses of one sample.

\*\*One or more replicates showed a concentration below the detection limit; therefore, the actual standard deviation could not be calculated.

† The concentration of soluble orthophosphate exceeded that of total phosphorus.

associated with salinity increases. From 11 to 13 m, the range of soluble ortho P concentrations was 0.039 to 0.044 mg P/l. There were too few samples at that depth to accurately assess the relationship between salinity and soluble orthophosphate concentrations.

Salinity levels (Table IV-9) during flood tide showed a gradual increase from surface to near bottom; at high tide this increase seemed to be even more pronounced. As the tide ebbed, the salinity difference from surface to bottom decreased. Comparison of the pattern of soluble ortho P concentrations relative to the tidal changes in salinity showed, at flood tide, no significant increase from surface to mid-depth but a decrease from mid-depth to near bottom. At high tide, there was a great difference from surface to mid-depth but no change from mid-depth to near bottom. As the tide ebbed, there was a decrease but a smaller one than had been found at high tide from the surface to mid-depth. From mid-depth to bottom soluble ortho P concentrations either decreased or did not change.

The total phosphorus concentrations near GBEC Buoy 11 varied greatly at all three depths measured. The surface total P concentrations ranged from <0.04 mg P/l (detection limit) to 0.19 mg P/l. As in the case of the soluble orthophosphate concentrations at the surface, the greater the surface salinity, the lower the total P concentration. This relationship did not hold true at mid-depth, where the concentration ranged from 0.05 to 0.12 mg P/l. The total P concentrations near the bottom ranged from <0.04 mg P/l (detection limit) to 0.16 mg P/l. Data from this depth were insufficient to assess the relationship between salinity and total phosphorus concentrations.

Near Buoy 11, total phosphorus-tidal change in salinity patterns were similar to those found for soluble ortho P concentrations. During rising tide there seemed to be no change in total P concentration from surface to near bottom. At high tide there was a large decrease in total P concentration from the surface to mid-depth, and an increase from mid-depth to bottom. As the tide began to ebb, the decrease in concentration from the surface to mid-depth, which was found at high tide, diminished. Closer to low tide, the pattern was either one of no significant change with depth or an increase from surface to mid-depth with a greater increase from mid-depth to near bottom.

The range of soluble orthophosphate concentrations at the surface near GBEC Buoy 7A (from 0.023 to 0.109 mg P/l) was much narrower than the surface range near Buoy 11. The range from mid-depth near Buoy 7A was 0.027 to 0.083 mg P/l, about the same as the mid-depth concentrations near Buoy 11. Likewise, concentrations near bottom (ranging from below detection limit (0.02 mg P/l) to 0.035 mg P/l) were about the same as those in Buoy 11 bottom waters. No relationship between soluble ortho P concentrations and the salinity at the surface were evident near Buoy 7A.

Compared to ranges at corresponding depths near Buoy 11, total phosphorus concentration ranges near Buoy 7A were narrower at the surface and near the bottom, and about the same at mid-depth. Total P concentrations at the surface near Buoy 7A ranged from 0.03 to 0.10 mg P/l, from 0.05 to 0.13 mg P/l at mid-depth and from 0.07 to 0.13 mg P/l near the bottom. Based on samples collected at Buoy 7A, there was no evident relationship between total P concentration and salinity.

The pattern of both phosphorus forms studied near Buoy 7A in relation to tidal changes showed that as the tide ebbed, there was a decrease in the concentrations from the surface to mid-depth. There was a smaller decrease in soluble ortho P concentration from mid-depth to bottom, whereas there was an increase in total P concentration at the bottom. As the tide ebbed more, the concentrations of both soluble ortho P and total P increased from the surface to mid-depth. Near the low tide, there was an increase in soluble ortho P and total P concentrations from the surface to mid-depth and no change from mid-depth to bottom.

The total range of soluble orthophosphate concentrations near Buoy 1 was relatively narrow, from <0.02 mg P/l (detection limit) to 0.043 mg P/l (Table IV-25). This range was found for all three sampling depths on three different dates. The concentrations of total P at Buoy 1 were, with one exception, between <0.02 mg P/l (detection limit) and 0.05 mg P/l (Table IV-25). The exception was a concentration of 0.28 mg P/l found at a 1-meter depth.

At low tide near Buoy 1, both total phosphorus and soluble orthophosphate concentrations showed no significant change from the surface to mid-depth. From mid-depth to bottom the soluble ortho P concentrations decreased, whereas those of total P showed no change.

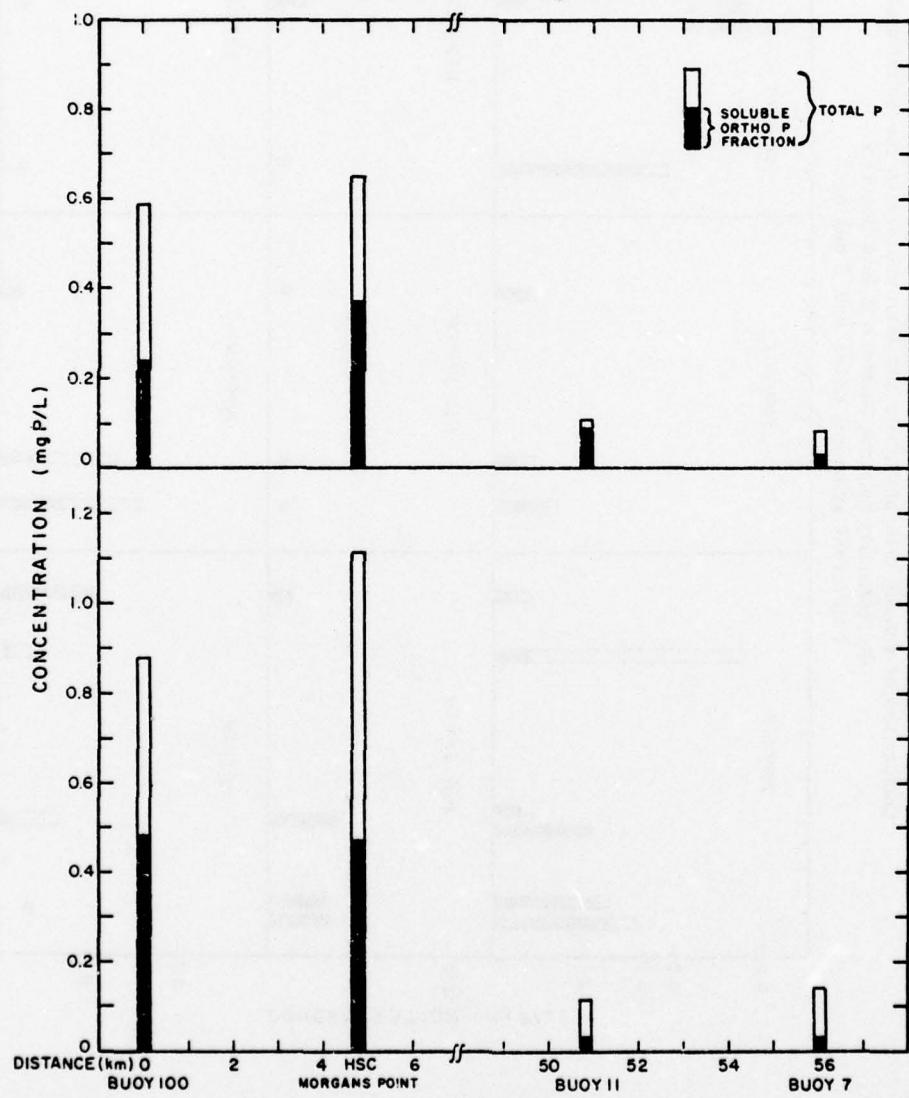
The ratio of total phosphorus to soluble ortho-phosphate did not seem to show a pattern with tides. In general, as Gulf of Mexico water advanced into the Galveston Entrance Channel during rising tide, it brought with it less contaminated, more saline water. The generally lower phosphorus concentrations in the bottom water are associated with the salt wedge. The tide seemed to influence the water from Buoy 11 samples more than it did others since this buoy was closest to the sources of contamination in the channel.

As shown in Figures IV-3 and 4 and Table IV-25, higher total phosphorus and soluble orthophosphate concentrations were generally found farther up the GBEC; concentrations in the HSC were as much as 24 times those found in the rest of the GBEC. Texas City Channel Turning Basin concentrations were as much as ten times greater than those found in the GBEC. It appears that both the HSC and Texas City Channel may be sources of phosphorus contamination for the GBEC. However, as Figure IV-4 seems to indicate, the higher phosphorus concentrations farther up the GBEC either were diluted or precipitated out during transport, for concentrations gradually diminished between Buoys 11 and 1. Concentrations from Buoy 1 and Grid Square 2 (in the GBEC disposal site) appeared to be consistently low throughout the sampling period. The fraction of total P which was soluble ortho P did not seem to follow a pattern through the GBEC.

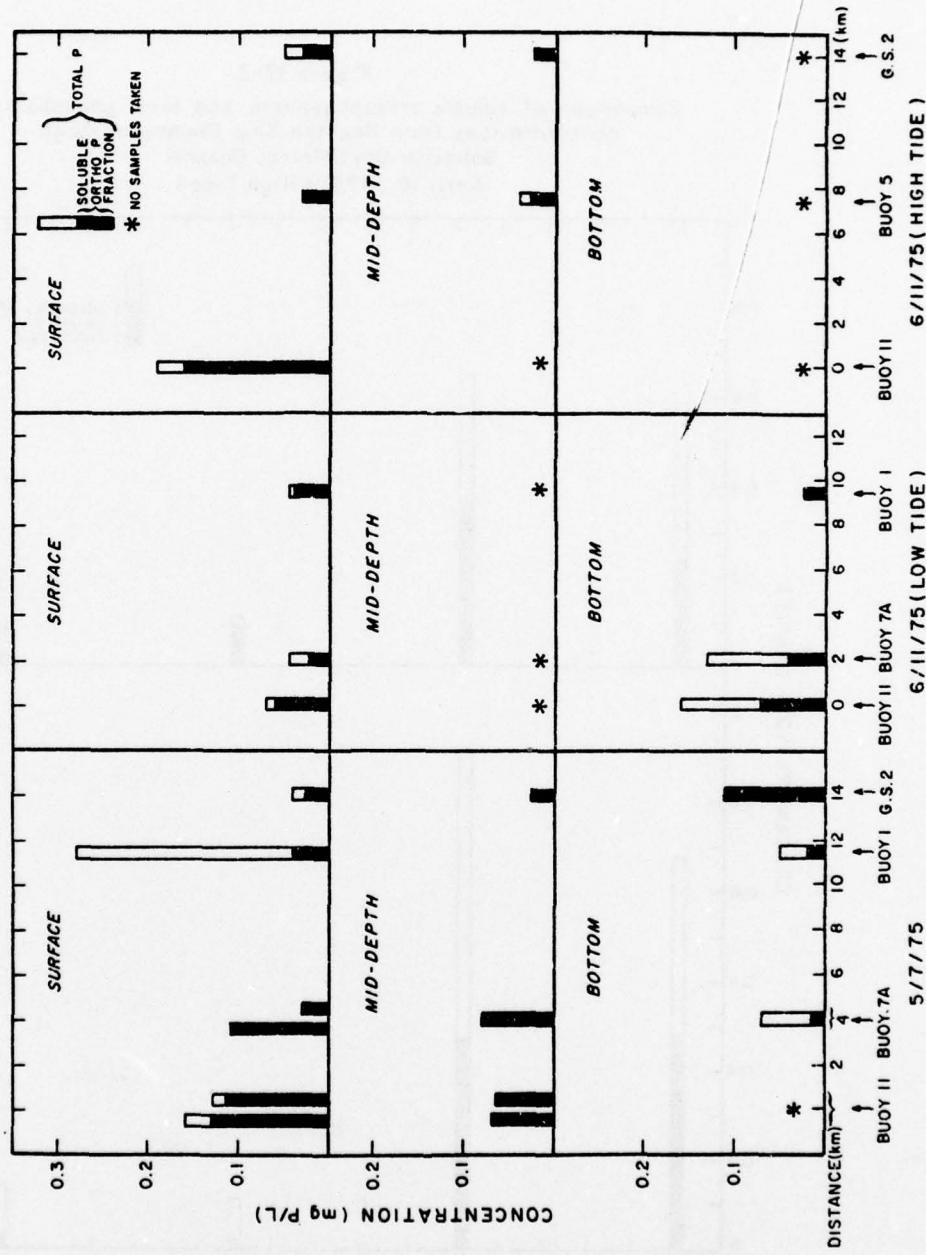
The variability range of both soluble orthophosphate and total phosphorus concentrations at all depths lessened from Buoy 11 moving seaward out the Galveston Inner Bar, Outer Bar and Entrance Channels. The variability also lessened as the effect of the tide diminished.

Disposal site water column. Table IV-26 and Table IV-27 show the mean concentrations of soluble orthophosphate and total phosphorus in the GBEC Disposal Site before disposal. With only two exceptions, the values for the soluble ortho P concentrations at all stations and dates were between <0.02 mg P/l (detection limit) and 0.038 mg P/l, which is generally lower than concentrations in the

**Figure IV-3**  
Comparison of soluble orthophosphate and total phosphorus concentrations from Houston Ship Channel through Galveston Bay Entrance Channel  
April 18, 1975 (High Tide)



**Figure IV-4**  
**Comparison of soluble orthophosphate and total phosphorus concentrations through  
 Galveston Bay Entrance Channel and Grid Square 2  
 ( Different sampling dates and 3 depths )**



**Table IV-26**  
**Pre-Disposal Soluble Orthophosphate and Total Phosphorus Concentrations**  
**in Galveston Bay Entrance Channel Disposal Site**

Sampling Location G.S.	Date Collected (1975)	Depth (m)	Soluble Ortho P		Total Phosphorus		Particulate Phosphorus	
			X	SD*	X	SD	X	SD
1	4/17	2	<0.02	~0.001**	0.03	0.005	~0.010	~0.006**
		9	<0.02	~0.002**	0.05	0.005	~0.030	~0.007**
	4/17	2	<0.02	~0.002	0.05	0.001	~0.030	~0.003**
		9	<0.02	~0.001**	0.08	0	~0.060	~0.001**
2		12	<0.02	~0.000***	0.03	0.006	~0.010	~0.006***
	5/6	2	0.031	0	<0.04	~0.0**	~0.009	~0
	5/6	2	0.025	0.001	<0.04	~0.0**	~0.015	~0.001**
	5/6	2	0.025	0.002	<0.02 +	~0.012**	~0	~0.014**
2	5/7	1	0.025	0.003	0.04	0.01	~0.015	~0.013
		6	0.028	0.003	<0.02 +	~0.01**	~0	~0.013**
	14	0.112	0.002		0.11 +	0.005	~0	0.008
		1	0.032	0.002	0.05	0.006	0.018	0.008
6/11		6	0.024	0.002	<0.02 +	~0	~0	~0.002**
	12	<0.02	0.001		0.03	0.006	~0.011	~0.007
	2	<0.02	~0.001**		0.06	0.005	~0.040	~0.006**
		13	0.034	0	0.11	0	0.076	0
6	4/17	2	<0.02	0.004	0.03	0.002	~0.01	~0.006
	4/17	2	<0.02	0.004	0.11	0	0.076	0
7	4/17	2	<0.02	0.004	0.03	0.002	~0.01	~0.006

(Continued)

Table IV-26 (Concluded)

Sampling Location G.S.	Date Collected (1975)	Depth (m)	Soluble Ortho P		Total Phosphorus		Particulate Phosphorus	
			$\bar{X}$	SD*	$\bar{X}$	SD	$\bar{X}$	SD
8	4/17	2	<0.02	~0.001**	0.03	0	~0.01	~0.001**
9	4/17	9	<0.02	~0.001**	0.02	0	~0	~0.001**
9	4/17	0	0.038	0.002	0.07	0	0.032	0.002
13	4/17	9	<0.02	~0.001**	0.07	0	~0.05	~0.001**
13	4/17	2	0.026	0.004	0.08	0.002	0.054	0.006
13	4/17	2	0.024	0.002	0.09	0.003	0.066	0.005
15	4/17	13	0.025	0.001	0.06	0.005	0.035	0.006
15	4/17	2	0.052	0.003	0.15	0.01	0.098	0.013
16	4/17	9	<0.02	~0.004**	0.13	0.005	~0.110	~0.009
16	4/17	2	<0.02	~0.004**	0.03	0.002	~0.010	~0.006
16	4/17	9.5	<0.02	~0.001**	0.10	0	~0.080	~0.001
22	4/17	2	0.029	0.001	0.04	0.005	0.011	0.006
22	4/17	9	0.023	0.002	0.09	0	0.067	0.002
23	4/17	2	<0.02	~0.001**	0.04	0	~0.020	~0.001
23	4/17	10	<0.02	~0.001**	0.16	0.05	~0.140	~0.006

\*Standard deviation based on triplicate analyses of one sample.

\*\*One or more of the replicates showed a concentration below the detection limit; therefore, the actual standard deviation could not be calculated.

† The concentration of soluble orthophosphate exceeded that of the total phosphorus.

Table IV-27  
Pre-Disposal Total Phosphorus Concentrations  
in Water Column near Galveston Bay Entrance  
Channel Disposal Site Buoys C and D  
(August 27, 1975)

Sampling Location	Depth (m)	Total Phosphorus	
		$\bar{X}$	SD
Buoy C	Surface	0.10	0.007
	3	0.03	0.017
	6	0.03	0.009
	9	0.08	0.004
	12	0.02	0.003
	15	0.02	0.009
	18	0.05	-
Buoy D	Surface	0.01	0.003
	3	0.02	0.001
	6	0.02	0.002
	9	0.01	0.002
	12	0.01	0.005
	15	0.03	0.002
	18	0.01	0.004

\*Standard deviation based on triplicate analyses of one sample.

Dash (-) indicates only one analysis made.

GBEC area. Further, the variability of soluble ortho P concentrations in G.S. 2 was much less than in the GBEC. This may be an indication that the variability in the more seaward grids would be less than at Grid Square 2. In a few instances the concentration seemed to vary with depth, but there was no consistent pattern.

Total phosphorus concentrations in the disposal area were also generally lower than in the channel area. With a few exceptions, most disposal site concentrations for all sampling dates were between <0.02 mg P/l (detection limit) and 0.11 mg P/l. Both soluble ortho P and total P levels were higher in Reference Grid Square 15 than in the other grid squares. Repeated sampling at G.S. 2 indicated that the total P concentrations did not vary widely from April to June.

A comparison of total P concentrations found in April with those found in August near G.S. 13 showed that there was no significant difference between the two. On August 27, 1975, total P concentrations at Buoy D were generally lower than those at Buoy C, which is closer to Galveston Bay and thus to many sources of contamination.

#### Characteristics of the Water Column During Disposal

The results of a series of nine dumps of dredged sediments monitored in this study are presented in this section. In each case, the sampling ship was positioned approximately 30 to 300 meters downcurrent from the disposal site. The physical and chemical characteristics of the water column before, during and after passage of the turbid plume arising from the dump were monitored. The presence of the turbid plume was indicated by a decreased percent transmission of the water. The proximity of the sampling vessel to the point of discharge enabled a comparison of the turbidity and the release of any contaminants for each dump monitored. The correlation between turbidity and changes in water quality is valid only when sampling takes place near the point of discharge. Otherwise, the suspended material in a water mass decreases as a function of the

particles' fall-velocities, while the released solutes remain in the same water mass.

During all disposal operations a marker buoy was used to locate the specified disposal site. The sampling boat would position itself along a line formed by the direction of the surface current flowing by the marker buoy. The distance from the boat to the buoy varied with each dump. All distances between the disposal site and the sampling ship reported in this study were visually estimated. Distances under 50 meters were estimated using an Optical Tapemeasure (M-100-Ranging, Inc., Rochester, N.Y.).

To monitor the disposal operations, the sampling vessel was positioned in a way such that the center of the turbid surface plume resulting from the disposal would pass directly beneath the sampling boat. The actual spot where the hopper dredge was to dump was determined by direction of current relative to the dump buoy. The general dump area was located by finding the dump buoy. The direction of the current one meter below the surface was then measured with a Bendix Q-15 current meter and Model 230 deck recorder. In some instances these current direction and velocity measurements were supplemented by the use of surface drogues and dye markers.

In most cases the hopper dredge McFarland passed between the sampling boat and the buoy. The deposition of the material occurred approximately when the bow of the dredge crossed an imaginary line between the sampling boat and the marker buoy (see Figure IV-5). On one occasion, Galveston Dump No. 1, the hopper dredge passed on the opposite side of the marker buoy from the sampling boat (See Figure IV-6).

Different sampling techniques were used for the taking of water samples, transmissometer readings and

**Figure IV-5**  
Disposal operation monitoring  
(Galveston Dump Nos. 2-7 and Texas City Dumps Nos. 1 and 2)

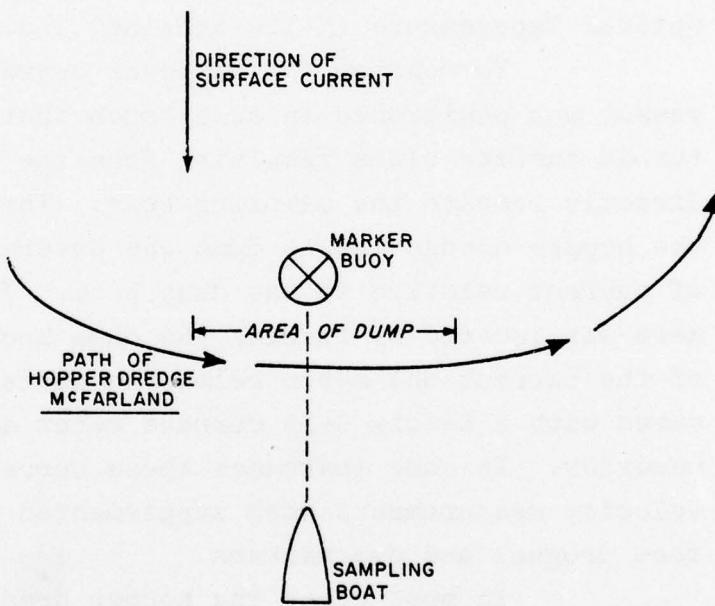
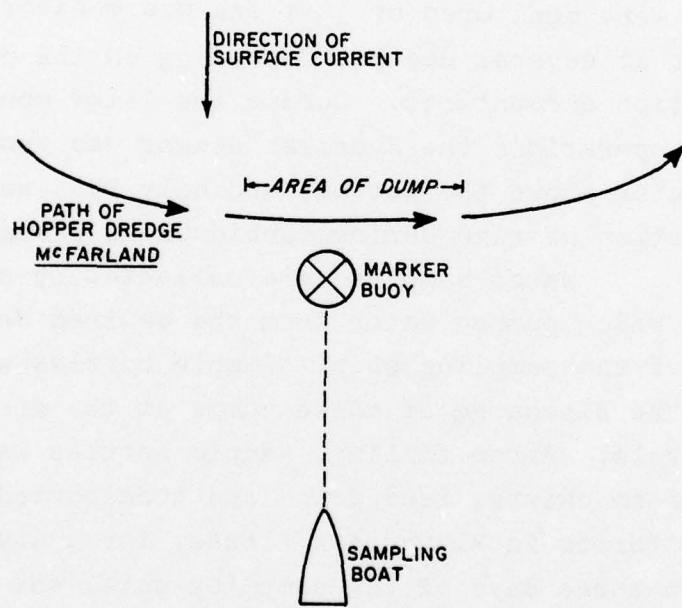


Figure IV-6  
Disposal operation monitoring  
(Galveston Dump No. 1)



Hydrolab readings. During the water sampling the objective was to take a few samples before and a large number of samples during and after passage of the turbid plume from specific depths. Generally, the samples were taken at one meter below the surface, mid-depth and one meter from the bottom. The transmissometer data were obtained to provide a description of the disposal plume. Readings were taken at various depths in the water column before, during and after the passage of the turbid plume. All times used were Central Daylight Savings time.

The Hydrolab unit measured temperature, D.O., salinity and pH at different depths. All parameters were monitored or just one was monitored at one or at several depths, depending on the particular situation encountered. During the later monitored disposal operations the Hydrolab sensor was generally left at one meter above the bottom, and only D.O. was measured as a function of time during turbid plume passage.

Water samples were collected by submersible pumps which pumped water from the desired depths to the deck of the sampling ship. Sample bottles were filled from the discharge of these pumps at the desired time intervals. After filling, sample bottles were placed in styrofoam chests, iced down and transported to the UTD laboratories in Richardson, Texas, for analysis. Usually within three days of the sampling date, the samples were filtered through a  $0.45\text{-}\mu$  pore size membrane filter and acidified with HCl. Analyses of the soluble constituents were performed on the filtrates. All samples were stored just above freezing prior to analysis.

Only one pump was used during August 28 and 29, 1975, dump monitoring operations. This pump was lowered to

the desired depth and allowed to flush. Then the sample was taken. The pump was used at three different depths (one meter below the surface, mid-depth and one meter above the bottom). After it became evident that this procedure was not producing a sufficient number of samples during the passage of the turbid plume, two more pumps were added. The three pumps took samples from each of the three depths throughout the monitoring period.

#### Galveston Dump No. 1

The first dumping operation monitored took place near Buoy B on August 28, 1975, at 11:39. The turbid surface plume arrived at 11:42 and passed at 11:48. The seas were 3 to 5 feet; the air temperature was 30°C, and the wind was approximately 10 miles per hour from the east. The water column depth was 12 meters. The sampling boat was located approximately 150 meters, azimuth 195° from Buoy B. The disposal of 1331 cubic yards of material dredged from GBEC Buoys 6 through 8 occurred about 20 meters to the far side of the marker buoy (See Figure IV-6). The current profile just before the disposal is found in Table IV-28.

Table IV-28

Current Profile just Prior to Disposal: Galveston Dump No. 1  
(August 28, 1975)

Depth (m)	Direction (azimuth °)	Magnitude (knots)	Magnitude (cm/sec)
1.5	195	1.6	82
3.0	190	1.6	82
4.6	197	1.1	57
6.1	187	1.1	57
7.6	185	1.0	51
9.1	180	0.5	26

Optical properties. Table IV-29 presents the percent light transmission data for Galveston Dump No. 1. Turbidity, as measured by percent transmission, was monitored at one-meter intervals in the water column during the dump. This method of monitoring the turbidity at the disposal site proved to be too time-consuming with only one transmissometer to properly define passage of the turbid plume. As a result, it was decided to monitor three depths within the water column--surface (2 meters), mid-depth and bottom--during subsequent disposal operations.

Temperature, dissolved oxygen, salinity and pH. The temperature, D.O., salinity and pH data obtained with the Hydrolab unit during Dump No. 1 are presented in Table IV-30. Readings for all the parameters were taken at 1, 2, 5, 10 and 11 meters. The concentrations of D.O. were plotted as a function of time, and no change in concentration could be detected (Figure IV-7) with this monitoring procedure. No change in any of the other parameters was noted during passage of the turbid plume.

Heavy metals. Data in Table IV-31 show the concentrations of soluble and total, i.e., acid leachable, heavy metals in water samples taken during the disposal period. There was a slight trend of manganese release with time after the dump. Samples taken three minutes and one minute before the surface turbid plume reached the sampling vessel contained 200 and 268  $\mu\text{g/l}$  soluble manganese (at 3 and 12 meters, respectively). Samples taken after the surface turbid plume passed the sampling vessel contained 280  $\mu\text{g/l}$  manganese at 12 meters, 385 and 315  $\mu\text{g/l}$  at 9 meters and 303  $\mu\text{g/l}$  manganese at one meter.

Table IV-29

Percent Transmission: Galveston Dump No. 1 near  
 Buoy B, Dredged Material from Galveston Bay  
 Entrance Channel Buoys 6 through 8

(August 28, 1975)

Time (hr:min:sec)	Depth (m)	Percent Transmission
11:39:00 - Dump occurred.		
11:40:00	1	48
11:41:00	2	45
11:42:00	3	15-48
11:43:00	4	18-45
11:45:00	5	32-48
11:52:00	6	38
11:53:00	7	40
11:53:15	8	36
11:53:45	9	35
11:54:15	10	32
11:54:30	11	35
11:55:15	12	18
11:56:00	13	8
11:56:15	14	4
11:57:00	15	2
11:57:30	16	1
11:59:00	2	52
11:59:30	3	52
12:00:15	4	51
12:01:15	5	50
12:02:15	6	48
12:02:30	7	46

(Continued)

Table IV-29 (Concluded)

Time (hr:min:sec)	Depth (m)	Percent Transmission
12:03:15	8	46
12:04:00	9	40
12:05:30	10	32
12:06:00	11	20
12:06:15	12	10
12:06:45	13	14
12:07:15	14	4
12:07:45	15	2
12:08:15	16	2

Ten-cm light path used.

Throughout the passage of the turbid surface plume there were no changes in concentrations of chromium, cadmium, mercury or arsenic. There was an apparent decrease in lead and copper concentrations at all depths. Nickel increased slightly during passage of the plume but decreased again after it had passed. Zinc concentrations varied but tended to decrease during and after the plume.

Nitrogen compounds. Results of the ammonium and nitrate analyses presented in Table IV-32 show that apparently this disposal operation had no discernible effect on ammonium concentrations. Ammonium concentrations were consistently below 0.05 mg N/l. Nitrate did not vary more than 0.03 mg N/l. This is expected because the dredged sediments were anoxic in nature and did not have any nitrate present.

Phosphorus compounds. There were insufficient data from Galveston Dump No. 1 (Table IV-33) to establish a definite trend in soluble orthophosphate behavior. However, it does appear that the concentration of soluble

Table IV-30  
Hydrolab Data: Galveston Dump No. 1 near Buoy B, Dredged Material  
from Galveston Bay Entrance Channel Buoys 6 through 8  
(August 28, 1975)

Time of Collection (hr:min)	Depth (m)	Temp (°C)	D.O. (mg/l)	Specific Conductance ( $\mu\text{hos}/\text{cm} \times 10^4$ )	Salinity (‰)	pH
11:31	1	28.5	7.6	3.8	24	8.5
11:31	2	28.5	7.0	3.8	24	8.5
11:31	5	28.5	6.8	3.8	24	8.5
		11:39 - Dump occurred.				
11:39	10	28.5	6.6	3.8	24	8.5
11:39	11	28.5	6.4	3.7	23	8.5
		11:42 - Turbid surface plume arrived at sampling location.				
11:43	11	28.5	6.4	3.5	22	8.5
11:44	10	28.5	6.6	3.9	25	8.5
11:45	5	28.5	6.7	3.8	24	8.5
11:46	2	28.5	6.8	3.8	24	8.5
		11:48 - Turbid surface plume passed sampling location.				
11:48	1	28.5	6.9	3.8	24	8.5
11:49	1	28.5	6.9	3.8	24	8.5
11:50	2	28.5	6.9	3.8	24	8.5
11:51	5	28.5	6.7	3.8	24	8.5
11:52	10	28.0	6.5	3.8	24	8.5
11:54	11	28.0	6.2	3.8	24	8.5

Figure IV-7  
Dissolved oxygen concentrations  
Galveston Dump No. 1 near Buoy B  
Dredged material from Galveston Bay Entrance Channel Buoys 6-8  
August 28, 1975

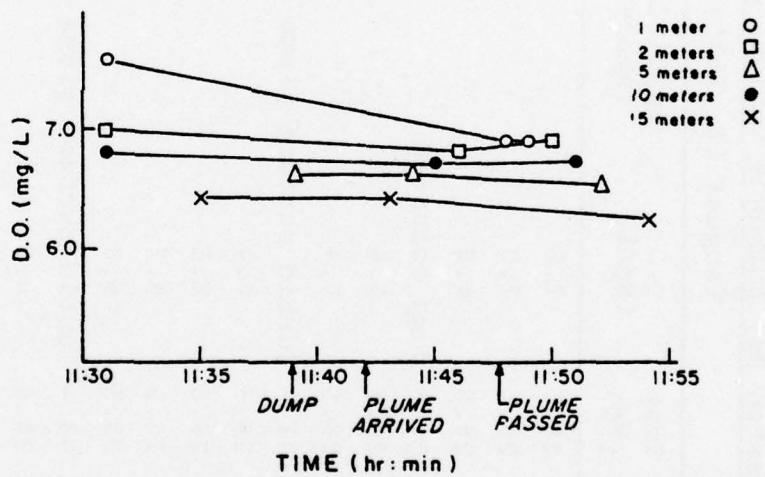


Table IV-31  
 Heavy Metal Concentrations: Galveston Dump No. 1 near Buoy B, Dredged Material  
 from Galveston Bay Entrance Channel Buoys 6 through 8  
 (August 28, 1975)  
 (µg/l)

Time of Collection (hr:min:sec)	Depth (m)	Mn SOL*	Mn TOT	Cr		Cd		Ni		Pb		Zn		Cu		Fe		Hg		As	
				SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT		
11:39:00	3	200	315	11:39	- Dump occurred.	9.8	11.1	11.7	-	9.4	10.3	2.8	-	4.3	177	<0.001	0.010	<2	<2		
11:41:00	12	268	467	<2	<2	1.0	1.0	10.4	30.7	7.7	10.9	14.0	14.7	4.0	-	99	921	0.010	0.010	<2	
11:42:00	1	210	210	<2	<2	0.8	-	8.6	12.9	5.3	6.9	15.9	-	2.8	-	22	151	0.010	0.010	<2	
11:45:00	1	210	292	<2	<2	0.9	-	9.2	-	6.9	8.5	9.4	-	4.0	-	54	727	0.010	0.010	<2	
11:48:00	3	292	292	<2	<2	0.8	0.9	17.2	-	8.5	9.3	11.5	-	1.6	-	6.0	-	0.010	0.010	<2	
11:52:00	9	385	385	<2	<2	0.6	0.6	3.7	12.3	10.1	11.7	10.6	-	2.4	-	6.1	-	<0.001	<0.001	<2	
11:53:00	12	280	280	<2	<2	0.9	0.9	9.8	-	5.3	8.5	12.3	-	2.0	5.2	172	1016	<0.001	0.010	<2	
11:54:00	1	303	-	<2	<2	0.7	0.8	4.3	11.1	7.7	8.5	13.1	-	4.0	-	109	-	0.010	-	<2	
11:57:00	9	315	400	<2	<2	0.8	0.8	19.0	-	6.1	9.3	10.0	-	1.6	4.4	30	796	<0.001	<0.001	<2	

\*In this and subsequent metal tables, SOL represents the soluble metals fraction that passed through a 0.45-µ pore size filter.  
 TOT represents the total metals fraction that was acid leachable with HCl at pH v1.  
 Dash (-) indicates data not available.

Table IV-32

Ammonium and Nitrate Concentrations: Galveston Dump  
No. 1 near Buoy B, Dredged Material from Galveston  
Bay Entrance Channel Buoys 6 through 8  
(August 28, 1975)

Time of Collection (hr:min)	Depth (m)	Ammonium (mg N/l)	Nitrate (mg N/l)
11:39 - Dump occurred.			
11:39	1	0.01	-
11:39	3	<0.01	0.07
11:39	6	0.02	-
11:40	9	0.01	-
11:41	12	0.02	0.07
11:42 - Turbid surface plume arrived at sampling location.			
11:42	1	<0.01	0.06
11:45	1	0.02	0.04
11:48 - Turbid surface plume passed sampling location.			
11:48	3	0.01	0.04
11:52	9	0.01	<0.04
11:53	12	0.02	0.05
11:54	1	0.02	0.05
11:55	3	0.01	-
11:56	6	0.01	-
11:57	9	0.01	0.04

---

In this and other nitrogen compound tables, a dash (-) indicates that the sample was not analyzed for that particular compound (unless otherwise indicated.)

Table IV-33

Soluble Orthophosphate Concentrations: Galveston DumpNo. 1 near Buoy B, Dredged Material from GalvestonBay Entrance Channel Buoys 6 through 8(August 28, 1975)

Time of Collection (hr:min:sec)	Depth (m)	Soluble Orthophosphate	
		$\bar{X}$	SD
11:39 - Dump occurred.			
11:39:00	3	0.134	0.002
11:41:00	12	0.208	0.002
11:42 - Turbid surface plume arrived at sampling location.			
11:42:00	1	0.179	0.002
11:45:00	1	0.127	0
11:48 - Turbid surface plume passed sampling location.			
11:48:00	3	0.018	0.002
11:52:00	9	0.012	-
11:53:00	12	0.011	-
11:54:00	1	0.456	0.005
11:57:00	9	<0.01	~0

Standard deviation based on triplicate analyses of one sample.

Dash (-) indicates only one analysis performed.

ortho P at the surface increased about three-fold after the turbid surface plume passed the sampling boat. The concentrations at 9 and 12 meters were less after the plume passed than at the time of disposal. The concentration at the surface was back to ambient levels when sampled one hour later.

Organic carbon, oil and grease. Water column samples collected during disposal operations undertaken at Buoy B on August 28 and 29, 1975, were analyzed for total

organic carbon (TOC), soluble TOC and oil and grease. For each disposal operation a composite sample was made from the subsamples collected before, during and after passage of the surface turbid plume. Composites of filtered samples ( $0.45 \mu$  pore size filter) were prepared from samples collected from each of the five disposal operations. Composites of nonfiltered samples were prepared on samples collected from the fourth and fifth dumps. No measurements were made of TOC, soluble TOC and oil and grease for Dumps No. 6 and 7 and Texas City Dump No. 1.

The concentrations of soluble TOC in samples composited before, during and after passage of the surface turbid plume in the first dump were 18.8, 6.9 and 8.4 mg/l, respectively. Based on these data, variability of total and soluble TOC seemed to follow a random pattern during the passage of the surface turbid plume. In the first dump soluble TOC decreased by 11.9 mg/l during the plume and increased by 1.5 mg/l past the plume. The soluble oil and grease content of these composite samples was less than 0.5 mg/l (the detection limit of the analytical procedure).

#### Galveston Dump No. 2

The second disposal near Buoy B on August 28, 1975, occurred at 12:55. The turbid surface plume arrived at 12:57 and passed at 13:00. Approximately 1236 cubic yards of material was dumped. The nautical and atmospheric conditions were the same as in the first dump, as was the water column depth. The sampling boat was located approximately 150 meters from the marker buoy at azimuth  $185^\circ$ . The dredged material from GBEC Buoys 6 through 8 was dumped as described in Figure IV-5. The hopper dredge was estimated to be approximately 100 meters off the bow of the sampling boat during disposal. The pre-disposal current profile is presented in Table IV-34.

Table IV-34  
Current Profile Just Prior to Disposal:  
Galveston Dump No. 2  
(August 28, 1975)

Depth (m)	Direction (azimuth °)	Magnitude (knots)	Magnitude (cm/sec)
1.5	180	1.7	87
3.0	187	1.8	93
4.6	180	1.5	77
6.1	185	1.2	62
7.6	185	0.9	46
9.1	188	0.6	31

Optical properties. The percent transmission for Galveston Dump No. 2 was monitored at 2 meters (surface), 8 meters (middle) and 14 meters (bottom). The presence of suspended dredged material at surface, middle and bottom was first observed within 1, 4 and 4.5 minutes of the dump, respectively. Figure IV-8 shows that percent transmission decreased at the surface and middle depths during passage of the turbid plume. No appreciable change was found for the bottom depth, which already had a low percent transmission, possibly from a preceding dump. These data show the need for more intensive monitoring during disposal in order to properly define the duration of the turbid plume at various depths.

Dissolved oxygen. Dissolved oxygen concentration data are shown in Figure IV-9. The D.O. stabilized at 6.5 mg/l for six minutes before an increase of 0.3 mg/l to 6.8 mg/l was observed three minutes after the turbid plume arrived. The readings returned to the

Figure IV-8  
Percent transmission  
Galveston Dump No. 2 near Buoy B  
Dredged material from Galveston Bay Entrance Channel Buoys 6-8  
August 28, 1975

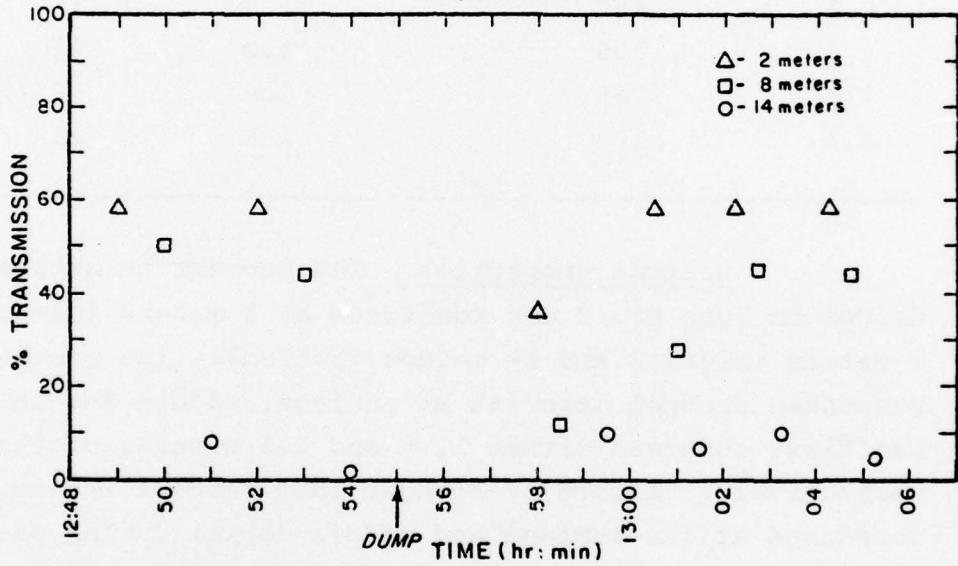
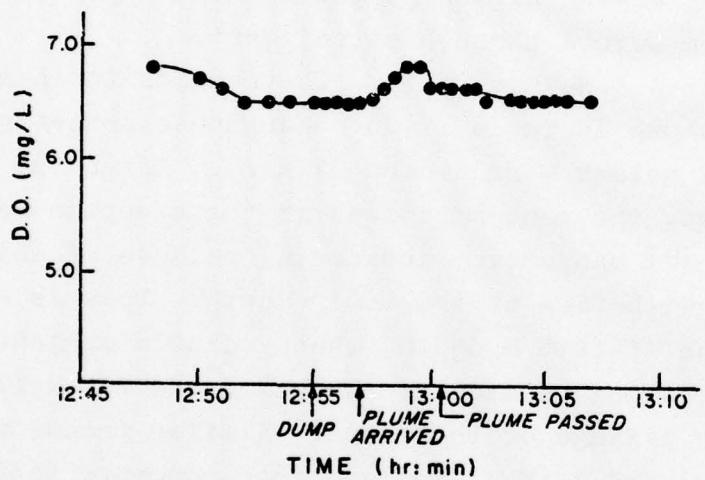


Figure IV-9  
Dissolved oxygen concentrations  
Galveston Dump No. 2 near Buoy B - Depth 12m  
Dredged material from Galveston Bay Entrance Channel Buoys 6-8  
August 28, 1975



pre-disposal level within five minutes after passage of the surface turbid plume. There were two possible causes for this increase in concentration. During the disposal operations, highly aerated water was sometimes used to wash out the material in the hopper after the hopper doors were opened. It was possible that this water was the cause for the increase. The other possible cause was that the movement of the dredged material downward caused a mixing of the higher oxygen content upper waters with the bottom waters through entrainment.

Heavy metals. The results for heavy metals are shown in Table IV-35. Manganese concentrations at 3 and 6 meters were 64 and 77  $\mu\text{g/l}$ . After the plume had passed, the concentrations at these depths were 64 and 112  $\mu\text{g/l}$  manganese, indicating release of soluble manganese with time at the lower depth. This is also seen at the 16-16.5 m depth, where soluble manganese was 105  $\mu\text{g/l}$  during passage of the plume and 215  $\mu\text{g/l}$  10 minutes after passage of the plume. Similar trends were seen with nickel and lead. Zinc and iron concentrations decreased slightly after the plume had passed.

Nitrogen compounds. The ammonium, organic N and nitrate data for Galveston Dump No. 2 are presented in Table IV-36. Ammonium concentrations were comparable to concentrations found in the location prior to disposal. With one exception (0.06 mg N/l at 12:55 at 3 m), ammonium levels never rose above 0.02 mg N/l. Organic N possibly shows some effects of the dump. The organic N concentration was 0.55 mg N/l when the turbid surface plume arrived, but decreased to 0.38 mg N/l five minutes after the turbid surface plume passed the sampling ship. The bottom water concentration pattern is not as clear. Higher readings were observed 3 and 15 minutes after disposal, but a much lower reading was obtained 5 minutes after the dump.

Table IV-35  
 Heavy Metal\* Concentrations: Galveston Dump No. 2 near Buoy B, Dredged  
 Material from Galveston Bay Entrance Channel Buoys 6 through 8  
 (August 28, 1975)

Time of Collection (hr:min:sec)	Depth (m)	Mn SOL TOT	Cr SOL TOT	Cd SOL TOT	Ni SOL TOT	Pb SOL TOT	Zn SOL TOT	Cu SOL TOT	Fe SOL TOT	Hg SOL TOT	As SOL TOT
12:50:00	6 77	<2 <2	1.7 1.9	6.5 -	7.8 10.0	12.1 12.3	3.3 3.8	4.8 4.40	0.010 0.100	<2 <2	
12:55:00	3 64	84 <2	2.9 -	3.3 -	7.8 -	6.5 -	3.8 4.3	16 12.3	0.010 0.010	<2 <2	
12:56:00	6 77	- <2	2.1 -	12.3 -	11.1 12.2	18.4 21.2	8.6 -	91 535	0.010 0.070	<2 <2	
12:57:00	1 84	- <2	1.9 -	5.7 8.4	10.0 12.2	5.0 19.3	3.8 5.7	79 915	<0.001 0.010	<2 <2	
12:57:30	12 98	- <2	1.6 -	4.1 5.7	8.9 13.3	7.0 12.8	4.3 5.7	24 586	<0.001 0.010	<2 <2	
12:58:00	16 105	- <2	2.8 -	8.4 11.6	12.2 16.7	9.3 14.8	4.3 7.1	200 -	<0.001 0.010	<2 <2	
13:00:00											
13:05:00	1 84	- <2	2.1 -	10.8 12.7	11.1 12.2	12.8 -	4.3 4.8	4.3 12.0	0.010 0.010	<2 <2	
13:05:30	3 64	- <2	1.6 -	2.9 4.9	8.9 8.9	16.8 -	6.2 -	92 -	0.010 0.010	<2 <2	
13:06:30	6 112	- <2	2.6 -	12.4 12.4	11.1 13.3	10.9 -	5.2 -	77 460	0.020 0.010	<2 <2	
13:07:30	9 215	- <2	1.5 -	11.3 -	15.3 -	7.2 -	8.3 -	28 481	<0.001 0.010	<2 <2	
13:08:00	12 158	- <2	2.8 -	10.0 -	9.3 -	9.6 -	8.3 -	76 871	0.010 0.010	<2 <2	
13:09:00	15 201	- <2	1.3 -	10.0 -	12.7 -	5.0 -	5.0 -	94 839	<0.001 0.010	<2 <2	
13:10:00	16.5 215	- <2	1.5 -	12.5 -	14.7 -	3.6 -	5.0 5.7	57 470	0.010 0.010	<2 <2	

\*For explanation of SOL and TOT see Table IV-31.

Dash (-) indicates no data available.

Table IV-36  
Nitrogen Data: Galveston Dump No. 2 near Buoy B,  
Dredged Material from Galveston Bay Entrance  
Channel Buoys 6 through 8  
(August 28, 1975)

Time of Collection (hr:min:sec)	Depth (m)	Organic N (mg N/l)	Ammonium (mg N/l)	Nitrate (mg N/l)
12:48:00	1	-	0.01	-
12:49:00	3	-	<0.01	-
12:50:00	6	0.43	0.01	0.05
12:51:00	9	-	<0.01	-
12:54:00	12	-	0.01	-
		12:55:00 - Disposal occurred.		
12:55:00	1	-	0.02	-
12:55:00	3	0.26	0.06	0.04
12:56:00	6	0.43	0.01	0.06
		12:57:00 - Turbid surface plume arrived at sampling location.		
12:57:00	1	0.55	0.01	<0.04
12:57:30	12	0.63	0.01	<0.04
12:58:00	16	0.83	0.01	0.05
		13:00:00 - Turbid surface plume passed sampling location.		
13:00:00	16	0.59	<0.01	<0.04
13:01:00	16	-	0.01	-
13:05:00	1	0.38	0.02	0.06
13:05:30	3	0.35	0.01	0.06
13:06:30	6	-	0.02	-
13:07:30	9	0.51	0.01	0.05
13:08:00	12	0.63	0.01	0.04
13:09:00	15	0.78	0.02	0.11
13:10:00	16.5	0.75	0.01	0.04

Dash (-) indicates no analysis made.

Nitrate levels ranged from <0.04 to 0.11 mg N/l throughout the monitoring period.

Phosphorus compounds. Table IV-37 shows the soluble orthophosphate concentrations during Galveston Dump No. 2. Possible soluble orthophosphate release at the time of disposal is indicated by the higher concentration of soluble ortho P found at 6 meters at 12:56 and at 16 meters at 13:00. Soluble orthophosphate concentrations returned to pre-disposal levels quickly as the turbid plume passed the sampling station. The greatest increase (from 0.05 to 0.54 mg P/l) was at the 6-meter depth, approximately 30 seconds after disposal. Within 10 minutes the concentration dropped to 0.06 mg P/l. Concentrations at the bottom increased 15-fold but again returned to pre-disposal levels within 9 minutes. What happened at the 3-and 12-meter depths is unclear because of the insufficient number of samples taken at these depths. At mid-depth and near bottom, soluble ortho P concentrations generally increased as the light transmission decreased.

Organic carbon, oil and grease. Concentrations of soluble TOC in samples composited before, during and after the second dump at the same site were 10.9, 17.7 and 20.2 mg/l, respectively. The cause of the elevated post-plume soluble TOC is unknown at this time. Soluble TOC increased by 6.8 mg/l during the plume passage and increased by 2.5 past the plume. It remained approximately twice the pre-plume arrival value after the surface plume passed. The soluble oil and grease content of the composite samples was less than 0.5 mg/l (the detection limit).

#### Galveston Dump No. 3

The third monitored disposal operation occurred at 14:30 on August 28 near Buoy D. The turbid surface plume arrived at 14:34 and passed at 14:36. The sea and atmospheric conditions were the same as in the earlier operations but the

Table IV- 37

Soluble Orthophosphate Concentrations: Galveston Dump  
No. 2 near Buoy B, Dredged Material from Galveston  
Bay Entrance Channel Buoys 6 through 8  
(August 28, 1975)

Time of Collection (hr:min:sec)	Depth (m)	Soluble Orthophosphate (mg P/l)
12:50:00	6	0.05
	12:55 - Dump occurred.	
12:55:00	3	<0.01
12:56:00	6	0.54
	12:57 - Turbid surface plume arrived at sampling location.	
12:57:00	1	0.01
12:57:30	12	0.01
12:58:00	16	0.01
	13:00 - Turbid surface plume passed sampling location.	
13:00:00	16	0.23
13:05:00	1	<0.01
13:05:30	3	0.17
13:06:30	6	0.06
13:07:00	9	<0.01
13:08:00	12	0.12
13:09:00	15	<0.01
13:10:00	16.5	<0.01

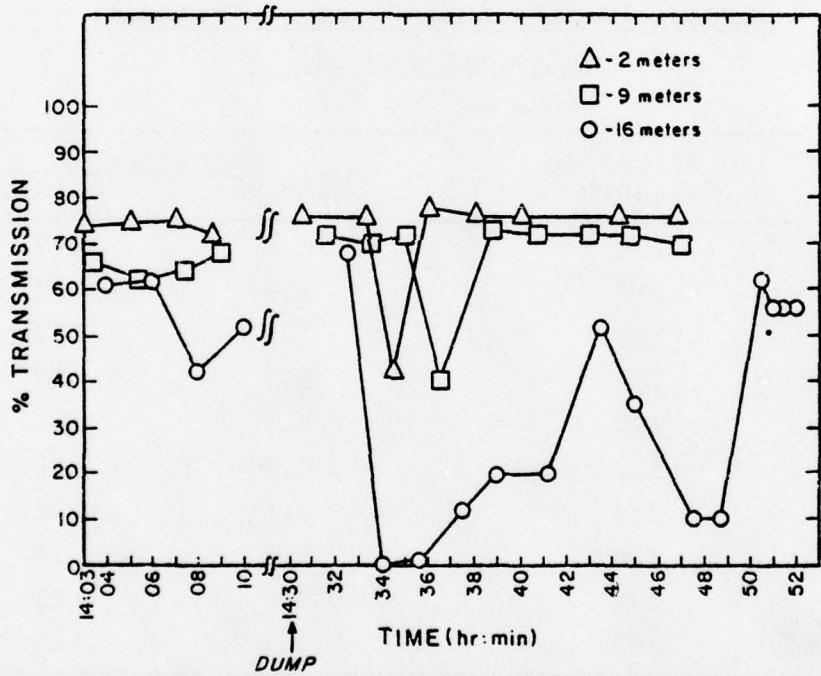
depth of the water column was 16 meters. The dredged material was obtained in the GBEC between Buoys 6 and 8. Approximately 1331 cubic yards of material was disposed during the dump. The sampling boat was located about 300 meters from Buoy D at azimuth 180°. The material was dumped between the sampling boat and the marker buoy, approximately 200 meters from the boat. Table IV-38 presents the pre-disposal current profiles.

Table IV-38  
Current Profile just Prior to Disposal:  
Galveston Dump No. 3  
(August 28, 1975)

Depth (m)	Direction (azimuth °)	Magnitude (knots)	Magnitude (cm/sec)
1.5	175	1.5	77
3.0	180	1.3	67
4.6	185	1.2	62
6.1	195	1.1	57
7.6	190	0.8	41
9.1	210	0.7	36
10.7	210	0.6	31
12.2	210	0.5	26
13.7	220	0.4	21
Bottom	220	0.2	10

Optical properties. Figure IV-10 shows the percent transmission at 2, 9 and 16 meters following Galveston Dump No. 3. The presence of suspended material at these depths was first observed 4.5, 6.5 and 4.0 minutes, respectively, following the disposal. As shown in Figure IV-10 , the greatest turbidity was found at the bottom depth, where turbid conditions persisted for 16 minutes.

**Figure IV-10**  
Percent transmission  
Galveston Dump No. 3 near Buoy D  
Dredged material from Galveston Bay Entrance Channel Buoys 6-8  
August 28, 1975



Dissolved oxygen. Dissolved oxygen data for Galveston Dump No. 3 (Figure IV-11) show that at 15 meters there was an increase in D.O., approximately 0.5 mg/l, just after the dump occurred. After the surface plume arrived, a drop of 1.0 mg/l D.O. from the baseline was observed. Ten minutes after disposal, the concentration of D.O. returned to the pre-disposal levels.

Heavy metals. Table IV-39 presents the water column concentrations of heavy metals monitored for Galveston Dump No. 3. Soluble manganese and lead concentrations at 1, 9 and 18 meters increased with time after the dump occurred and remained elevated after the plume passed. Zinc, iron and nickel concentrations increased during plume passage but decreased afterwards to pre-disposal levels. There were no changes in chromium, cadmium, copper, mercury or arsenic as a result of this disposal operation.

Nitrogen compounds. Although the ammonium concentration remained essentially the same for all surface and mid-depth samples in Galveston Dump No. 3 (Table IV-40), it increased four to five-fold near the bottom when the plume reached the sampling ship. Just three minutes later, when the plume had apparently passed, the concentration at the bottom essentially returned to the detection limit of the analytical procedure used for these samples. Of the first three disposal operations, only this dump showed an effect on ammonium concentrations. However, all ammonium concentrations were 0.05 mg N/l or below. Organic N concentrations increased from 0.30 mg N/l before disposal to as high as 1.99 mg N/l after the turbid surface

Figure IV-II  
Dissolved oxygen concentrations  
Galveston Dump No. 3 near Buoy D - Depth 15m  
Dredged material from Galveston Bay Entrance Channel Buoys 6-8  
August 28, 1975

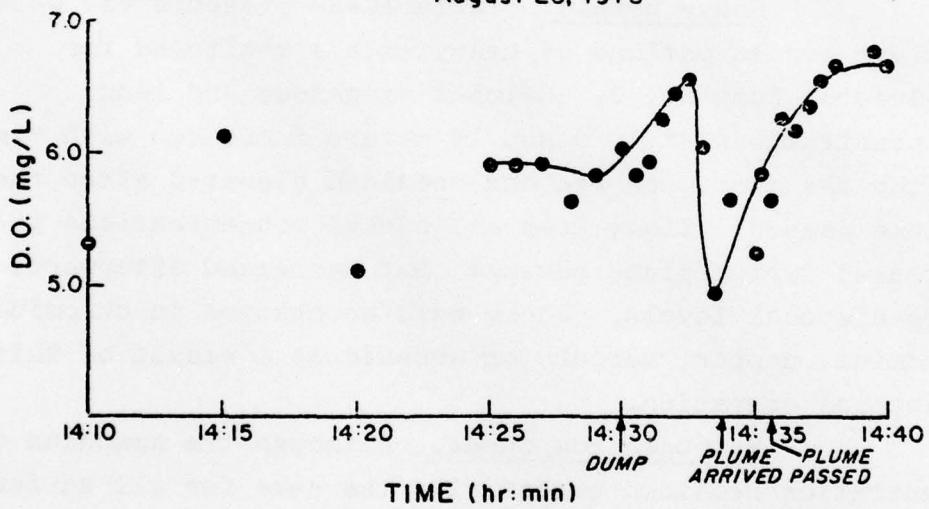


Table IV-39  
 Heavy Metal\* Concentrations: Galveston Dump No. 3 near Buoy D,  
 Dredged Material from Galveston Bay Entrance  
 Channel Buoys 6 through 8  
 (August 28, 1976)

Time of Collection [hr:min:sec]	Depth (m)	Mn SOL TOT	Cr		Cd		Ni		Pb		Zn		Cu		Fe		Hg		As	
			SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT
14:02:00	1	186 -	<2	<2	1.5 -	-	10.0 -	-	8.0 -	-	6.9	14.6	6.1	10.3	26	65	0.003	0.003	<2	<2
14:04:00	9	158 150	<2	<2	1.7 -	-	11.3 -	-	12.7 -	-	6.1	-	7.8	-	17	-	0.003	0.003	<2	<2
14:05:00	18	129 144	<2	<2	1.3 -	-	7.5 -	-	9.3 -	-	3.6	6.4	5.0	-	21	45	<0.001	0.003	<2	<2
14:32:30	1	186 -	<2	<2	1.3 -	-	10.0 -	-	11.3 -	-	1.0	29.8	3.9	-	11	-	<0.001	0.003	<2	<2
14:33:00	9	201 -	<2	<2	1.5 -	-	10.0 -	-	12.0 -	-	8.5	24.0	5.6	-	16	-	0.003	0.003	<2	<2
14:34:30	18	158 -	<2	<2	1.5 -	-	10.0 -	-	8.0 -	-	11.4	-	5.0	-	131	-	<0.001	0.013	<2	<2
14:35:00	1	243 -	<2	<2	1.7 -	-	12.5 -	-	16.0 -	-	11.0	-	5.6	-	43	-	<0.001	0.006	<2	<2
14:35:30	9	201 -	<2	<2	2.0 -	-	12.5 -	-	14.0 -	-	15.7	-	10.5	-	69	281	0.003	0.003	<2	<2
14:36:00	18	143 -	<2	<2	1.3 -	-	11.3 -	-	9.3 -	-	9.0	-	5.0	-	92	-	0.003	0.016	<2	<2
14:37:00	1	186 -	<2	<2	1.3 -	-	10.0 -	-	10.7 -	-	3.8	9.0	4.4	4.7	24	-	0.003	0.003	<2	<2
14:38:00	9	201 -	<2	<2	1.3 -	-	10.0 -	-	14.0 -	-	8.6	13.5	6.1	-	28	-	0.003	0.003	<2	<2
14:39:00	18	172 -	<2	<2	1.9 -	-	10.0 -	-	39.3 -	-	11.8	-	8.9	-	47	-	<0.001	0.006	<2	<2

\*For explanation of SOL and TOT see Table IV-31.

Dash (-) indicates no data available.

Table IV-40  
Nitrogen Data: Galveston Dump No. 3 near Buoy D,  
Dredged Material from Galveston Bay Entrance

<u>Channel Buoys 6 through 8</u>				
(August 28, 1975)				
Time of Collection (hr:min:sec)	Depth (m)	Organic N (mg N/l)	Ammonium (mg N/l)	Nitrate (mg N/l)
14:02:00	1	0.35	0.01	0.06
14:04:00	9	0.30	0.02	1.50*
14:05:00	18	0.31	<0.01	0.06
	14:30:00 - Disposal occurred.			
14:32:30	1	0.35	0.01	0.05
14:33:00	9	0.39	0.01	0.04
	14:34:00 - Turbid surface plume arrived at sampling location.			
14:34:30	18	0.36	0.04	*
14:35:00	1	0.35	0.01	0.05
14:35:30	9	0.19	0.01	0.06
	14:36:00 - Turbid surface plume passed sampling location.			
14:36:00	18	1.99	0.05	0.05
14:37:00	1	0.35	0.01	0.06
14:38:00	9	0.38	0.02	0.06
14:39:00	18	1.19	0.01	0.05

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\*These samples appear to have been contaminated.

plume passed the sampling site. As expected, disposal apparently had no effect on nitrate concentrations.

Phosphorus compounds. Table IV-41 presents the soluble orthophosphate data for Galveston Dump No. 3. The greatest increase (53-fold) in the soluble ortho P concentrations occurred at the 9-m depth. In less than three minutes, soluble ortho P returned to the concentrations present 30 minutes before disposal. There appears to be an inverse relationship between soluble orthophosphate concentration and light transmission. Data seem to indicate that soluble ortho P was released as the turbid plume of dredged material passed although surface concentrations of soluble orthophosphate did not appear to change during this disposal operation. However, no surface water was taken just prior to 14:35 hours, when the turbidity pattern would have indicated an increase in soluble ortho P concentration, were such an increase to occur.

The concentration pattern of soluble orthophosphate near the bottom during Galveston Dump No. 3 is not clear because of the limited number of samples collected. It appeared to rise during the monitoring period. However, since bottom sampling ceased nine minutes after the dump, it is not possible to determine the extent or duration of this increase.

Organic carbon, oil and grease. Concentrations of soluble TOC in composite samples collected before, during and after the third dump were 4.8, 5.1 and 5.0 mg/l, respectively. Data on soluble TOC in the third dump showed no significant change before, during and after passage of the surface turbid plume at the 95 percent confidence level. The soluble oil and grease content of the composite samples was less than the detection limit (0.5 mg/l).

Table IV-41  
Soluble Orthophosphate Concentrations: Galveston Dump  
No. 3 near Buoy D, Dredged Material from Galveston  
Bay Entrance Channel Buoys 6 through 8  
(August 28, 1975)

Time of Collection (hr:min:sec)	Depth (m)	Soluble Orthophosphate (mg P/l)	
		$\bar{X}$	SD
14:02:00	1	< 0.01	~ 0.001
14:04:00	9	< 0.01	~ 0.001
14:05:00	18	0.016	0.002
	14:30 - Dump occurred.		
14:32:30	1	< 0.01	~ 0
14:33:00	9	0.154	0.001
	14:34 - Turbid surface plume arrived at sampling location.		
14:34:30	18	0.024	0.001
14:35:00	1	< 0.01	~ 0
14:35:30	9	0.531	0.008
	14:36 - Turbid surface plume passed sampling location.		
14:36:00	18	0.076	0.001
14:37:00	1	< 0.01	~ 0.002
14:38:00	9	< 0.01	~ 0
14:39:00	18	0.171	0.002

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Standard deviation calculated from triplicate analyses of one sample. The approximate standard deviations indicate that one or more of the replicates showed a concentration below the detection limit.

#### Galveston Dump No. 4

The fourth dump that was monitored occurred near Buoy D at 12:58 on August 29. The turbid surface plume arrived at 13:00 and passed the sampling boat at 13:02. The distance from the sampling boat to the buoy was approximately 55 meters, azimuth 220°. The wind was from a southerly direction and was measured at 11 miles per hour. The disposal of the dredged material from GBEC Buoys 1 through 3 occurred as in Figure IV-5. The distance between the dredge and the sampling vessel was approximately 30 meters. The surface currents were determined by use of drogues and compass and were found to be approximately 1 knot (51 cm/sec) at azimuth 220°. Approximately 1067 cubic yards of material were disposed of during the dump.

Optical properties. Figure IV-12 shows the distribution pattern of material for Galveston Dump No. 4. The data show that the suspended material was distributed at each depth monitored (2, 8 and 14 meters). The suspended material took 2.75, 3.25 and 2.25 minutes to reach the monitoring location at surface, mid-depth and bottom, respectively. As in Dump No. 3, the greatest turbidity was in the bottom depth, where turbid conditions persisted for ten minutes. Secchi depths were read both prior to disposal and 37 minutes after Galveston Dump No. 4. They were 2.5 meters both times.

#### Temperature, dissolved oxygen, salinity and pH.

Table IV-42 presents Hydrolab data for Galveston Dump No. 4. The Hydrolab unit was placed at 14 meters and readings were made of temperature, D.O., salinity (specific conductance) and pH. Figure IV-13 shows that just after the plume arrived, there was a drop of 1.7 mg/l in the D.O. concentration. The D.O. returned to the pre-disposal

**Figure IV-12**  
Percent transmission  
Galveston Dump No.4 near Buoy D  
Dredged material from Galveston Bay Entrance Channel Buoys I-3  
August 29, 1975

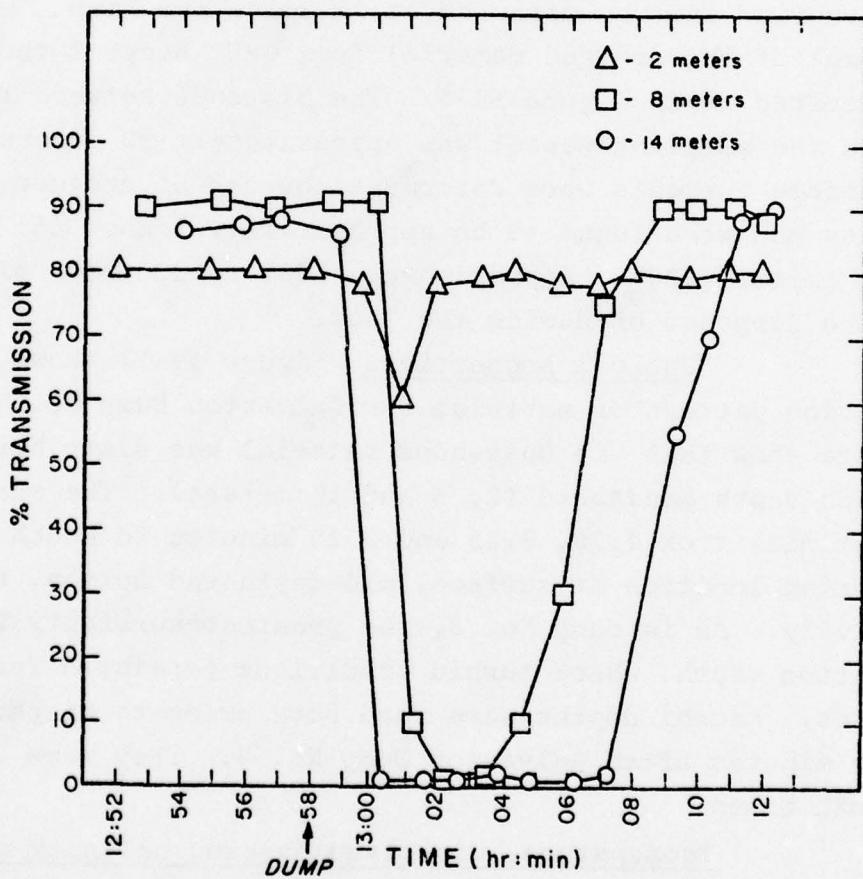


Table IV-42

Hydrolab Data: Galveston Dump No. 4 near Buoy D\*, Dredged Material from

Galveston Bay Entrance Channel Buoys 1 through 3

Time of Collection (hr:min.sec)	Temp (°C)	D.O. (mg/l)	Specific Conductance ( $\mu\text{mhos/cm} \times 10^4$ )	Salinity (°/oo)	pH
12:47:30	29	6.5	4.3	28	8.3
12:54:30	29	6.6	4.8	31	8.2
12:55:00	29	6.5	4.8	31	8.2
12:57:00	29	6.5	4.8	31	8.2
		12:58 - Dump occurred.			
12:58:00	29	6.5	4.8	31	8.2
12:58:15	29	6.6	4.8	31	8.2
12:58:45	29	6.5	4.8	31	8.2
12:59:15	29	6.5	4.8	31	8.2
		13:00 - Turbid surface plume arrived at sampling location.			
13:00:00	29	6.5	4.8	31	8.2
13:00:30	29	4.8	4.7	30	8.1
13:01:00	29	5.5	4.7	30	8.1
13:01:30	29	6.0	4.7	30	8.2
13:02:00	29	6.4	4.8	31	8.2
		13:02 - Turbid surface plume passed sampling location.			
13:03:00	29	6.3	4.8	31	8.2
13:04:00	29	6.5	4.7	30	-

(Continued)

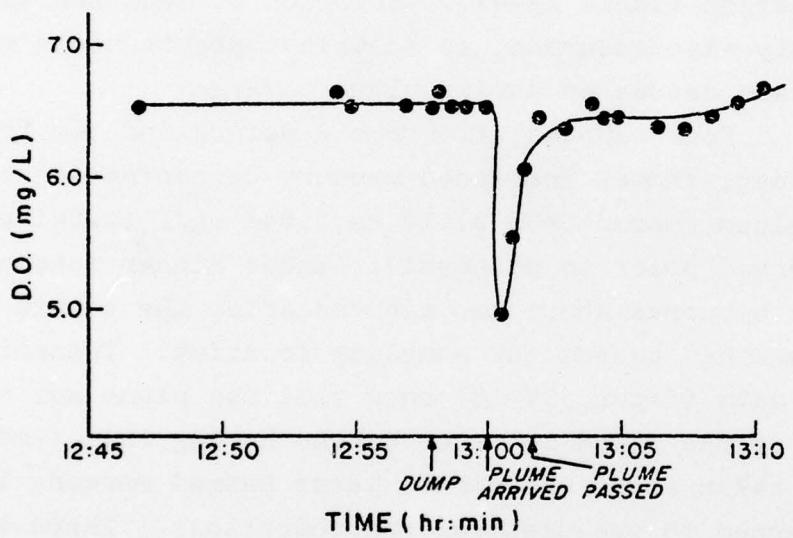
Table IV-42 (Concluded)

Time of Collection (hr:min:sec)	Temp (°C)	D.O. (mg/l)	Specific Conductance ( $\mu$ mos/cm $\times 10^4$ )	Salinity (‰)	pH
13:04:30	29	6.4	-	-	-
13:05:00	29	6.4	4.7	30	8.2
13:05:30	-	-	-	-	-
13:06:30	29	6.3	4.7	30	8.2
13:07:30	29	6.3	4.7	30	8.2
13:08:30	29	6.4	4.7	30	8.2
13:09:30	29	6.5	4.7	30	8.2
13:10:30	29	6.6	4.7	30	8.2

# Depth - 14 m.

Dash (-) indicates no reading taken.

Figure IV-13  
Dissolved oxygen concentrations  
Galveston Dump No.4 near Buoy D - Depth 14 m  
Dredged material from Galveston Bay Entrance Channel Buoys 1-3  
August 29, 1975



levels ten minutes after the dump occurred. Table IV-42 shows that there was no significant change either in temperature or salinity during the disposal operations.

Heavy metals. No manganese release was observed in Galveston Dump No. 4; in fact, manganese concentrations appeared to decrease toward the end of the turbid plume passage, possibly because of dilution and/or precipitation (Table IV-43). Sorption of lead and zinc apparently also occurred, as soluble concentrations of both metals decreased during plume passage.

Four samples, two from 8 meters and two from 14 meters deep, showed increased mercury concentrations. These values ranged from 0.010 to 0.048  $\mu\text{g/l}$  ( $0.003 \mu\text{g/l}$  was observed prior to disposal). These higher concentrations occurred about two minutes after the turbid surface plume had passed the sampling location. Transmissometer data (Figure IV-12) show that the plume was still present at the 8-and 14-meter depths during this time. Samples taken about one minute later showed mercury levels had returned to pre-disposal concentrations. There appeared to be a slight elevation in mercury concentrations in the surface waters, but this was declining at the end of the sampling period.

Nitrogen compounds. The results of nitrogen compound analysis for Dump No. 4 are presented in Table IV-44. A sudden increase in ammonium concentrations in the surface and mid-depth water samples was observed at 13:03:30. A very sharp increase in organic N concentration (to 7.24 mg N/l) was observed in the surface water at 13:02:30. However, by 5 minutes after the turbid surface plume passed the sampling ship, concentrations decreased and seemed to stabilize. Organic N concentrations in the mid-depth water almost doubled. However, by 10

Table IV-43  
 Heavy Metal\* Concentrations: Galveston Dump No. 4 near Buoy D  
Dredged Material from Galveston Bay Entrance  
Channel Buoys 1 through 3  
 (August 29, 1975)

Time of Collection (hr:min:sec)	Depth (m)	Mn SOL	Mn TOT	Cr		Cd		Ni		Pb		Zn		Cu		Fe		Hg		As	
				SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT
12:54:00	14 186	-	<2	<2	1.7	-	11.3	-	9.3	-	17.8	-	7.2	-	58	431	0.003	0.003	<2	<2	
12:59:30	14 201	-	<2	<2	1.5	-	12.5	-	14.7	-	13.8	-	5.6	-	35	344	<0.001	0.003	<2	<2	
				13:00 - Turbid surface plume arrived at sampling location.												18	46	<0.001	<0.001	<2	<2
13:00:30	1 172	-	<2	<2	1.5	-	10.0	-	12.7	-	12.8	-	8.3	-	13	103	0.003	0.003	<2	<2	
13:01:30	8 186	-	<2	<2	1.7	-	10.0	-	10.0	-	7.2	-	4.4	-							
				13:02 - Turbid surface plume passed sampling location																	
13:02:30	1 123	160	<2	<2	2.1	-	-	-	3.6	59.8	13.2	92.1	6.1	28.1	37	1100	0.003	0.039	<2	<2	
13:03:00	8 105	-	<2	<2	<0.5	-	-	-	3.1	-	7.3	-	2.6	-	9	-	<0.001	0.023	<2	<2	
13:03:30	8 -	-	-	<2	-	<0.5	-	2.4	-	-	-	-	-	7.2	-	480	<0.001	0.003	<2	<2	
13:03:50	14 105	182	<2	<2	<0.5	<0.5	0.7	16.8	3.1	37.9	8.5	59.9	3.5	21.2	25	1700	0.003	0.016	<2	<2	
13:04:15	8 88	111	<2	<2	<0.5	<0.5	6.6	-	2.0	88.0	9.6	30.9	3.5	12.7	13	900	0.016	-	<2	<2	
13:04:30	14 -	147	<2	<2	<0.5	2.2	3.3	5.9	4.0	14.6	7.0	22.0	2.6	6.7	227	900	0.010	-	<2	<2	
13:05:30	8 35	200	<2	<2	<0.5	<0.5	2.7	4.5	1.7	13.1	7.9	24.7	5.7	8.2	155	900	0.048	-	<2	<2	
13:06:00	14 18	200	<2	<2	<0.5	<0.5	4.1	12.9	<1	26.3	2.5	44.2	2.8	15.2	<5	1100	0.023	0.023	<2	<2	
13:06:30	1 14	126	<2	<2	0.7	-	3.6	-	<1	7.3	2.4	10.8	4.0	4.2	<5	-	0.006	0.010	<2	<2	
13:07:15	14 25	200	<2	<2	0.6	-	2.8	14.0	<1	30.6	1.4	54.3	2.8	18.7	8	1100	0.006	0.016	<2	<2	
13:09:45	14 56	165	<2	<2	0.7	-	3.6	7.7	<1	14.6	2.3	18.8	3.6	7.2	15	1000	0.006	0.006	<2	<2	
13:11:30	8 29	108	<2	<2	<0.5	<0.5	2.8	-	<1	5.8	2.0	5.4	2.8	-	<5	22	0.006	0.026	<2	<2	
13:12:15	1 40	133	<2	<2	<0.5	<0.5	4.1	-	<1	5.8	1.6	3.7	2.3	3.7	<5	55	0.003	0.023	<2	<2	

\*For explanation of SOL and TOT see Table IV-31.  
 Dash (-) indicates no data available.

Table IV-44  
Nitrogen Data: Galveston Dump No. 4 near Buoy D,  
Dredged Material from Galveston Bay Entrance  
Channel Buoys 1 through 3  
(August 29, 1975)

Time of Collection (hr:min:sec)	Depth (m)	Organic N (mg N/l)	Ammonium · (mg N/l)	Nitrate (mg N/l)
12:52:00	1	-	0.01	-
12:53:00	8	-	0.01	-
12:54:00	14	0.30	0.02	0.05
	12:58 - Disposal occurred.			
12:58:30	1	-	0.01	-
12:58:45	8	-	0.02	-
12:59:30	14	0.35	0.01	0.10
	13:00 - Turbid surface plume arrived at sampling location.			
13:00:30	1	0.87	0.01	0.06
13:01:30	8	0.30	0.06	0.05
	13:02 - Turbid surface plume passed sampling location.			
13:02:30	1	7.24	0.36	0.09
13:03:00	8	-	0.15	0.06
13:03:30	8	0.27	0.01	0.05
13:03:45	1	-	0.01	-
13:03:50	14	1.31	0.01	0.05
13:04:00	1	-	0.01	-
13:04:15	8	0.66	0.02	0.07
13:04:30	14	0.65	0.03	0.08
13:05:30	8	0.63	0.01	0.08
13:06:00	14	2.05	0.01	0.05
13:06:30	1	0.39	0.01	0.13
13:06:45	8	-	0.01	-
13:07:15	14	2.07	0.01	0.10

(Continued)

Table IV-44 (Concluded)

Time of Collection (hr:min:sec)	Depth (m)	Organic N (mg N/l)	Ammonium (mg N/l)	Nitrate (mg N/l)
13:08:30	1	-	0.02	-
13:09:00	8	-	0.01	-
13:09:45	14	1.02	0.02	0.07
13:11:00	14	-	0.01	-
13:11:30	8	0.26	0.02	0.07
13:12:15	1	0.43	<0.01	0.05

Dash (-) indicates no analysis made.

minutes after the surface plume passed, concentrations apparently returned to pre-disposal levels. Table IV-44 shows a time lag between the increase of organic N concentrations in the surface and mid-depth water. This lag was related to the fact that the surface current velocity was considerably higher than mid-depth or bottom current velocity.

In the bottom water, organic N concentrations showed at least two maxima. There was a sharp increase (to 1.31 mg N/l) five minutes after the disposal, followed by a decrease. Eight minutes after disposal a second, sharper increase was observed. Nitrate concentrations started increasing in the surface water about five minutes after disposal but returned to ambient concentrations by 14 minutes after the dump. In the bottom and mid-depth water, nitrate concentrations did not show any clear pattern of variation, although concentrations at both depths exhibited several maxima.

Phosphorus compounds. Data in Table IV-45 show that soluble ortho P concentrations during Dump No. 4

Table IV-45

Soluble Orthophosphate Concentrations: Galveston  
Dump No. 4 near Buoy D, Dredged Material from  
Galveston Bay Entrance Channel Buoys 1 through 3

(August 29, 1975)

Time of Collection (hr:min:sec)	Depth (m)	Soluble Orthophosphate (mg P/l)
12:54:00	14	0.447
	12:58 - Dump occurred.	
12:59:30	14	< 0.01
	13:00 - Turbid surface plume arrived at sampling location.	
13:00:30	1	0.289
13:01:30	8	< 0.01
	13:02 - Turbid surface plume passed sampling location.	
13:02:30	1	0.547
13:03:00	8	0.018
13:03:30	8	< 0.01
13:03:50	14	0.254
13:04:15	8	0.077
13:04:30	14	0.186
13:05:30	8	0.261
13:06:00	14	0.013
13:06:30	1	< 0.01
13:07:15	14	0.012
13:09:45	14	< 0.01
13:11:30	8	< 0.01
13:12:15	1	< 0.01

Concentration based on one analysis of one sample.

appeared to increase at all three depths during this disposal operation. Concentrations increased 25 to 55 fold, but returned to ambient levels within a 6- to 8-minute period. These increases occurred shortly after a rapid decrease in light transmission (Figure IV-12). It appears that the smallest reduction in light transmission and the greatest release of soluble ortho P occurred in the surface waters. The sample taken at 14 m at 12:54 also showed a higher concentration of soluble ortho P. This value could be related to residual effects from previous dumps or could be a spurious point as this high concentration was found prior to the dump and most baseline concentrations found were not that erratic.

Organic carbon, oil and grease. Soluble TOC concentrations in composite samples from the fourth dump were 11.2, 23 and 918 mg/l, respectively (before, during and after turbid plume passage). TOC in samples composited before, during and after passage of the surface turbid plume were 25.8, 38.4 and 38.3, respectively. The oil and grease and soluble oil and grease content before, during and after plume passage composite samples was <0.5 mg/l.

#### Galveston Dump No. 5

The last dump monitored near Buoy D on August 29 occurred at 14:27. The turbid surface plume arrived at 14:28 and passed at 14:29. The sampling boat was 100 meters from the marker buoy. As the dredge passed between the sampling boat and the buoy, disposing of 1115 cubic yards of the material from GBEC Buoys 1 through 3, the distance from the boat to the dredge was approximately 80 meters. The pre-disposal currents and other conditions were identical to those for Dump No. 4.

Optical properties. Depicted in Figure IV-14 are turbidity data for Galveston Dump No. 5. Percent transmission was monitored at 2 meters (surface), 8 meters (middle) and 14 meters (bottom). The suspended material took one minute (surface), 4 minutes (middle) and 4.5 minutes (bottom) to reach the sampling vessel. Again, the bottom depth showed the greatest turbidity. However, unlike bottom plumes observed in Galveston Dumps No. 3 and 4, the bottom plume in this disposal operation developed after the surface and middle plumes. In addition, the turbidity measured at 14 meters persisted for over one hour. The surface depth showed the same type of turbidity pattern as was observed during Galveston Dump No. 4.

Dissolved oxygen. Figure IV-15 presents the readings of D.O. taken at 14 meters. The plot of these data shows that five minutes after the dumping occurred, the D.O. concentrations dropped 1.5 mg/l. Several minutes later another depression in D.O. was seen. Unlike previous dumps, there was not a return to the initial concentrations within ten minutes of disposal. The concentrations did not stay at one level but fluctuated slightly below the pre-disposal levels.

Heavy metals. Table IV-46 presents water column concentrations of heavy metals for Galveston Dump No. 5. This disposal followed the last one by about 1.5 hours. Due to the larger number of samples analyzed, a well-defined picture of release and sorption was possible. There was an indication of manganese release (about 90  $\mu\text{g/l}$ ) in the bottom (16 m) samples. Iron concentrations fluctuated during the sampling period, with several samples showing values above pre-disposal levels. There was no indication of release or sorption of the other metals.

Figure IV-14  
 Percent transmission  
 Galveston Dump No. 5 near Buoy D  
 Dredged material from Galveston Bay Entrance Channel Buoys 1-3  
 August 29, 1975

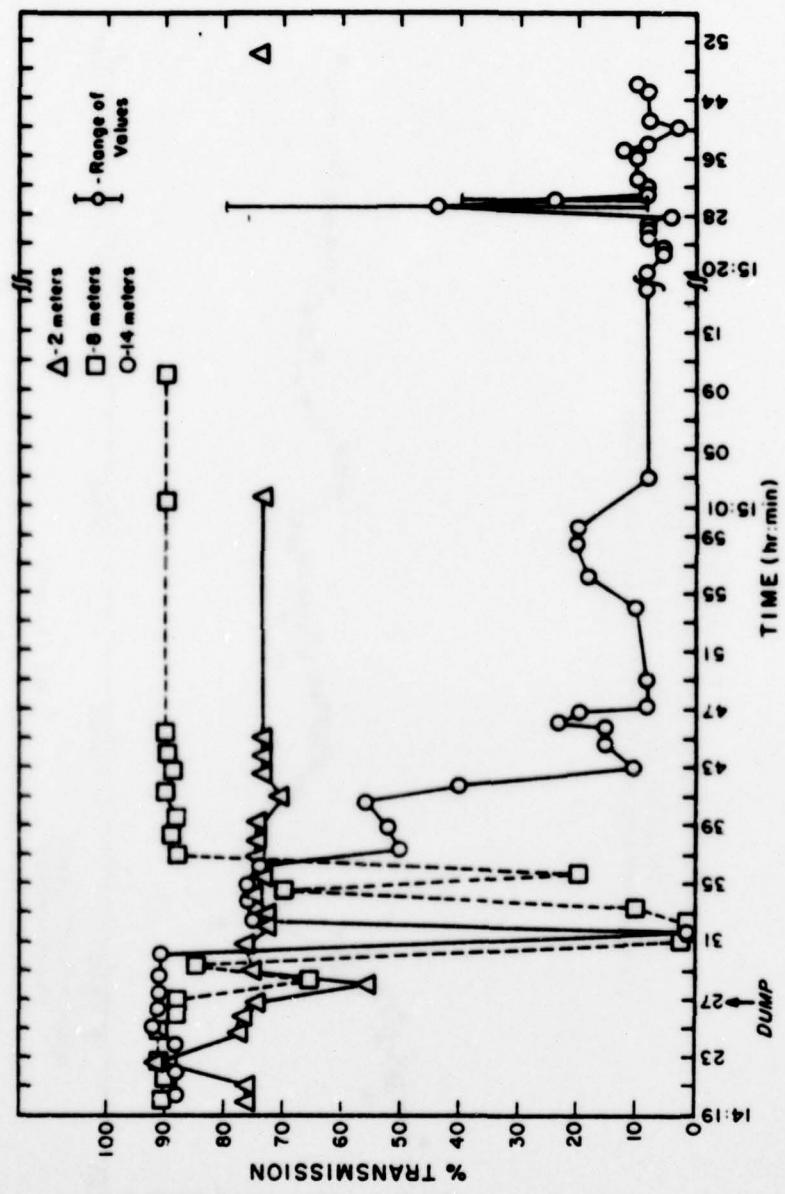


Figure IV-15  
Dissolved oxygen concentrations  
Galveston Dump No 5 near Buoy D-Depth 14 m  
Dredged material from Galveston Bay Entrance Channel Buoys 1-3  
August 29, 1975

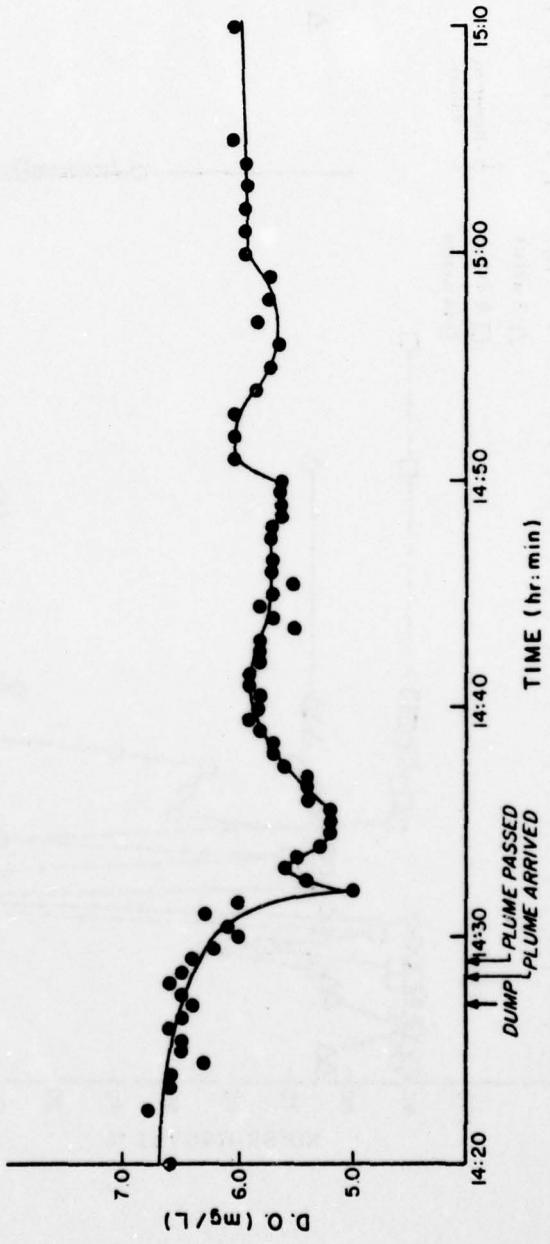


Table IV-46  
 Heavy Metal Concentrations: Galveston Dump No. 5 near Buoy D,  
 Dredged Material from Galveston Bay Entrance Channel  
Buoys 1 through 3  
 (August 29, 1975)  
 (ug/l)

Time of Collection (hr:min:sec)	Depth (m)	Mn		Cr		Cd		Ni		Pb		Zn		Cu		Fe		Hg		As	
		SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT		
14:26:30	2	96	-	<2	<2	1.1	-	8.1	-	7.5	-	1.5	7.9	4.1	-	<5	72	0.016	-	<2	<2
14:27:00	8	69	-	<2	<2	1.1	-	9.0	-	10.0	-	3.5	5.2	3.2	-	<5	19	0.006	0.006	<2	<2
14:28:00	16	48	-	<2	<2	0.9	0.9	9.0	-	8.3	-	1.2	6.8	3.6	-	54	0.006	0.023	<2	<2	
14:28:30	2	89	-	<2	<2	0.9	0.8	8.1	-	7.5	-	<0.5	5.4	3.6	-	6	66	0.003	0.006	<2	<2
14:29:45	8	140	-	2	1.1	1.7	0.0	12.2	17.7	-	3.3	17.9	6.2	7.4	17	17	0.006	0.023	<2	<2	
14:30:30	16	82	-	<2	<2	1.4	-	6.7	7.1	7.5	-	4.8	17.5	4.5	-	<5	920	0.003	0.010	<2	<2
14:30:45	2	115	123	<2	<2	1.0	1.2	2.3	12.4	7.3	20.3	3.3	18.4	3.0	8.0	11	63	0.003	0.006	<2	<2
14:31:15	16	140	-	<2	<2	1.5	-	7.3	8.3	16.4	16.4	2.2	4.0	8.2	-	9	390	0.003	0.006	<2	<2
14:31:30	8	81	-	<2	<2	0.9	-	3.6	4.9	13.3	-	12.5	-	3.1	-	11	27	0.003	0.006	<2	<2
14:32:00	16	55	89	<2	<2	1.2	1.3	9.5	28.5	6.3	12.4	4.5	42.1	5.0	10.0	<5	1200	0.006	0.010	<2	<2
14:32:30	8	156	210	<2	<2	1.4	1.8	7.3	11.9	15.0	-	4.0	16.5	6.5	7.4	<5	21	0.006	0.006	<2	<2
14:32:45	16	29	280	<2	<2	1.7	-	2.5	23.8	13.3	38.9	3.4	33.9	1.8	26.8	<5	16,300	0.006	0.030	<2	<2
14:33:00	2	89	-	<2	<2	1.1	-	8.1	-	56.9	-	2.7	6.3	4.5	4.0	<5	85	0.006	0.006	<2	<2
14:33:30	16	41	123	<2	<2	1.1	-	9.5	12.8	10.0	44.3	4.1	62.3	5.0	22.8	<5	1500	0.003	0.023	<2	<2
14:33:45	16	135	-	<2	<2	0.7	-	5.2	22.8	12.4	52.6	5.1	49.8	2.8	19.8	35	10,700	0.006	0.020	<2	<2

(Continued)

Table IV-46 (Continued)

Time of Collection (hr:min:sec)	Depth (m)	Mn		Cr		Cd		Ni		Pb		Zn		Cu		Fe		Hg		As	
		SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT		
13:34:30	16	123	144	<2	<2	1.1	1.5	9.5	14.0	11.3	35.2	2.0	40.1	3.6	14.1	<5	6800	0.006	0.016	<2	
14:35:15	16	175	263	<2	<2	1.5	1.6	9.0	17.8	11.1	24.7	4.9	33.1	7.5	15.3	30	10200	0.003	0.049	<2	
14:35:30	16	171	-	<2	<2	0.6	1.7	12.4	14.8	12.4	33.4	10.8	36.1	6.9	13.1	639	6900	0.003	0.023	<2	
14:36:15	16	55	171	<2	<2	1.1	-	7.1	21.2	10.0	29.7	4.7	30.7	4.1	11.1	17	6600	0.003	0.010	<2	
14:36:30	16	69	-	<2	<2	0.9	-	10.5	19.6	8.8	32.5	2.4	39.6	4.1	13.1	<5	6800	0.003	0.010	<2	
14:37:00	16	-	245	-	<2	-	1.2	-	18.6	-	37.5	-	22.7	-	18.3	-	10200	<0.001	0.043	<2	
14:37:30	8	140	162	<2	<2	1.5	1.8	9.7	-	13.7	16.9	5.6	10.5	6.2	-	9	2700	0.006	-	<2	
14:39:45	16	189	-	<2	0.9	-	17.2	-	16.9	21.5	13.3	27.5	6.7	8.1	2300	4800	0.006	0.023	<2		
14:39:45	8	123	245	<2	<2	1.4	1.6	8.0	12.7	15.0	16.3	2.9	17.7	7.5	8.3	10	4100	0.003	0.016	<2	
14:40:20	16	140	103	<2	<2	1.5	1.7	8.7	15.1	15.0	20.5	1.6	15.4	5.5	10.7	6	6200	0.003	0.030	<2	
14:42:00	16	129	210	<2	<2	1.6	-	1.0	14.6	8.0	29.0	11.7	22.6	2.8	10.1	32	4200	0.023	-	<2	
14:43:45	16	123	103	<2	<2	1.7	-	8.0	13.5	20.3	14.8	2.0	17.2	6.2	9.8	9	4700	0.006	0.006	<2	
14:43:45	16	105	158	<2	<2	1.7	-	8.7	14.1	19.0	21.9	7.9	31.3	5.8	10.7	9	4100	0.010	0.010	<2	
14:46:30	2	100	158	<2	<2	1.4	1.6	2.1	13.0	8.7	19.1	4.5	14.8	2.2	8.3	<5	53	0.006	0.010	<2	
14:47:15	8	123	210	<2	<2	1.4	-	6.7	11.9	19.0	21.9	7.0	36.6	6.5	6.8	12	19	0.016	0.006	<2	

(Continued)

Table IV-46 (Concluded)

Time of Collection (hr:min:sec)	Depth (m)	Mn		Cr		Cd		Ni		Pb		Zn		Cu		Fe		Hg		As	
		SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT
14:47:45	16	140	175	<2	<2	1.4	-	7.7	16.5	15.0	30.4	4.0	20.9	7.2	13.5	16.1	7700	0.003	0.016	<2	<2
14:50:15	16	156	158	<2	<2	1.2	1.3	8.3	13.8	12.4	19.1	11.6	18.6	6.5	8.3	13	3700	0.016	0.016	<2	<2
14:53:15	16	-	228	-	<2	-	1.7	-	12.2	-	16.3	-	12.6	-	7.4	-	2700	0.006	0.006	<2	<2
15:02:12	16	193	210	<2	<2	1.4	1.5	8.0	12.2	15.0	-	9.6	12.6	6.2	7.4	58	3200	0.006	0.010	<2	<2
15:11:45	16	29	158	<2	<2	1.3	-	1.4	13.5	8.0	26.2	3.3	17.6	1.2	7.7	<5	2700	0.006	0.006	<2	<2
15:16:45	2	14	140	<2	<2	1.3	1.8	1.6	11.9	8.0	10.6	2.1	16.9	2.8	8.3	10	60	0.010	-	<2	<2
15:17:30	8	71	175	<2	<2	1.1	-	1.9	8.0	8.7	19.0	7.7	-	1.6	5.8	175	-	0.006	0.010	<2	<2
15:18:30	16	175	193	<2	<2	1.5	-	9.0	13.0	15.0	17.7	5.2	16.0	6.5	8.0	6	3200	0.006	0.006	<2	<2

For explanation of SOL and TOT see Table IV-31.  
Dash (-) indicates no data available.

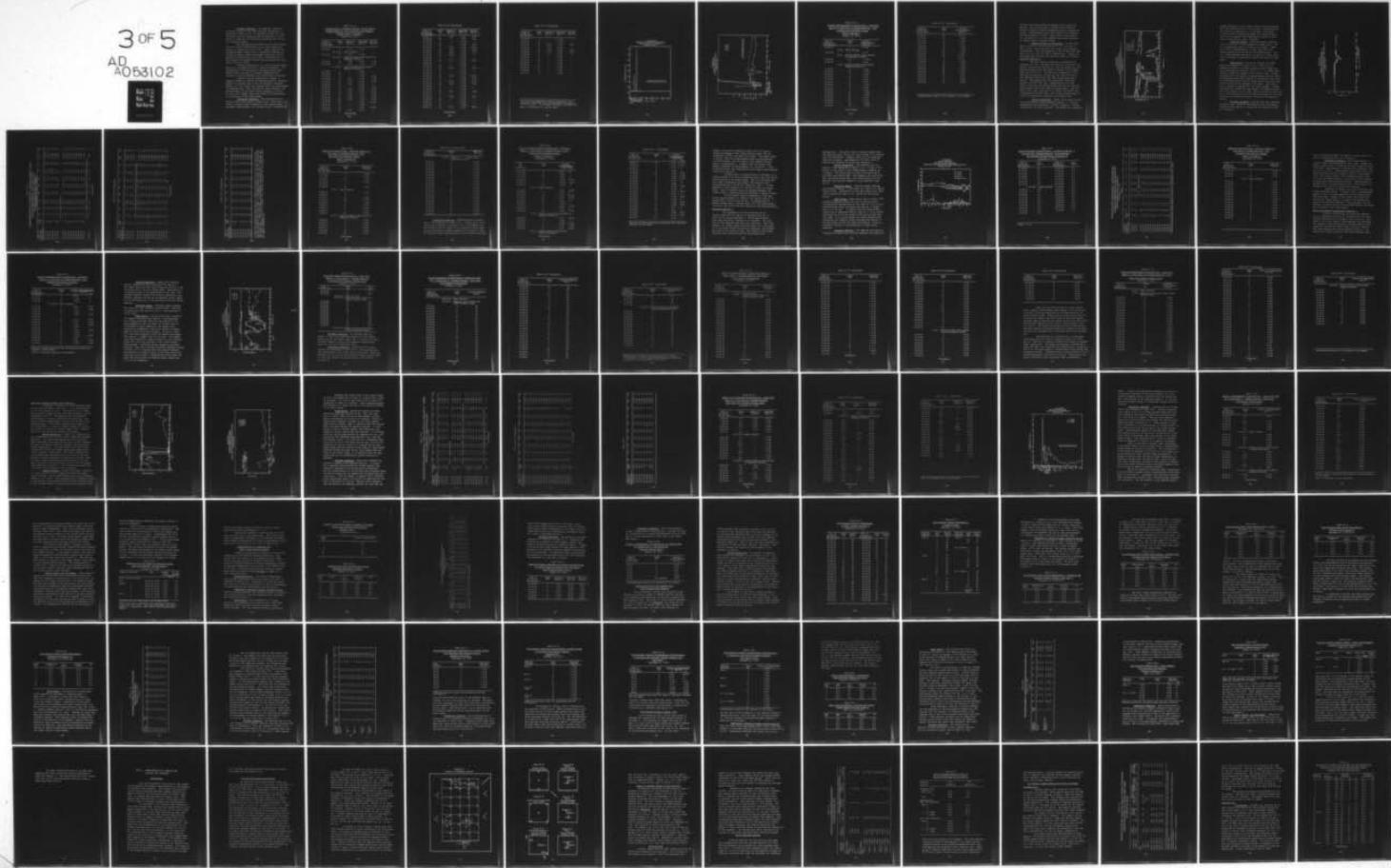
AD-A053 102 TEXAS UNIV AT DALLAS RICHARDSON CENTER FOR ENVIRONME--ETC. F/6 13/2  
AQUATIC DISPOSAL FIELD INVESTIGATIONS, GALVESTON, TEXAS, OFFSHO--ETC(U)  
DEC 77 G F LEE, P BANDYOPADHYAY, J BUTLER DACW64-75-C-0071

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Nitrogen compounds. The ammonium, organic N and nitrate data for the fifth disposal operation are presented in Table IV-47. As described in Part III, the detection limit for ammonium had been adjusted to <0.05 mg N/l to expedite the analytical procedures for this and all subsequent dumps.

The ammonium concentrations in the bottom waters and the nitrate concentrations at all three depths are plotted in Figures IV-16 and IV-17. These indicate that dredged sediment disposal had a significant influence on the bottom waters, where very sharp fluctuations in the ammonium concentrations can be seen. Concentrations in the surface and mid-depth waters remained below the <0.05 mg N/l detection limit.

Nitrate concentrations in surface and mid-depth water also increased little as a result of disposal. Concentrations in the bottom water increased sharply five minutes after the dump, but dropped immediately and returned to the pre-disposal level after about 35 minutes.

Disposal also had apparently no effect on organic nitrogen at surface and mid-depth waters. However, organic N concentrations in the bottom waters increased sharply (to 2.67 mg N/l) four minutes after the plume passed the sampling ship. About ten minutes after disposal, the concentrations in the bottom waters decreased a little, but were still higher than in the samples collected prior to the arrival of the turbid plume.

Phosphorus compounds. The concentrations of soluble ortho P are listed in Table IV-48. There was no release of soluble ortho P apparent in the surface waters. At mid-depth (approximately 8 m) soluble ortho P concentrations

Table IV- 47  
Nitrogen Data: Galveston Dump Nc. 5 near Buoy D  
Dredged Material from Galveston Bay Entrance  
Channel Buoys 1 through 3  
(August 29, 1975)

Time of Collection (hr:min:sec)	Depth (m)	Organic N (mg N/l)	Ammonium* (mg N/l)	Nitrate (mg N/l)
14:26:30	2	0.34	< 0.05	-
	14:27:00	-	Dump occurred.	
14:27:00	8	0.25	< 0.05	-
	14:28:00	-	Turbid surface plume arrived at sampling location.	
14:28:00	16	0.36	< 0.05	0.05
14:28:30	2	0.40	< 0.05	0.06
	14:29:00	-	Turbid surface plume passed sampling location.	
14:29:30	2	-	< 0.05	-
14:29:45	16	-	< 0.05	-
14:29:45	8	-	< 0.05	0.09
14:30:45	2	0.27	< 0.05	0.08
14:31:15	16	0.27	< 0.05	0.08
14:31:30	8	0.31	< 0.05	-
14:32:00	16	-	< 0.05	0.22
14:32:30	8	0.38	< 0.05	0.09
14:32:45	16	2.67	< 0.05	< 0.04
14:33:00	2	0.42	< 0.05	0.09
14:33:30	16	1.25	0.11	0.10
14:33:45	16	2.32	0.16	0.04
14:34:30	16	-	< 0.05	< 0.04
14:34:45	2	-	< 0.05	-
14:35:15	16	-	< 0.05	< 0.04
14:35:30	16	0.87	< 0.05	-

(Continued)

Table IV-47 (Continued)

Time of Collection (hr:min:sec)	Depth (m)	Organic N (mg N/l)	Ammonium* (mg N/l)	Nitrate (mg N/l)
14:36:15	16	1.35	< 0.05	0.09
14:36:30	16	-	0.38	0.12
14:36:45	2	-	< 0.05	-
14:37:00	16	-	< 0.05	0.71
14:37:30	8	0.42	< 0.05	< 0.04
14:37:45	16	0.74	0.10	0.12
14:39:45	8	0.35	< 0.05	0.12
14:40:20	16	0.50	< 0.05	-
14:41:00	2	-	< 0.05	-
14:42:00	16	0.47	< 0.05	0.12
14:42:45	2	-	< 0.05	-
14:43:30	8	-	< 0.05	-
14:43:45	16	0.47	< 0.05	0.13
14:44:30	2	-	< 0.05	-
14:45:15	8	-	< 0.05	-
14:45:45	16	0.42	< 0.05	< 0.04
14:46:30	2	-	< 0.05	0.11
14:47:15	8	0.35	< 0.05	0.14
14:47:45	16	0.90	< 0.05	0.12
14:48:30	2	-	< 0.05	-
14:49:30	8	-	< 0.05	-
14:50:15	16	0.32	< 0.05	0.09
14:51:45	2	-	< 0.05	-
14:53:15	8	0.09	< 0.05	0.11
14:55:30	16	-	< 0.05	-
15:00:30	2	-	< 0.05	-
15:01:15	8	-	< 0.05	-
15:02:15	16	0.31	< 0.05	0.09

(Continued)

Table IV-47 (Concluded)

Time of Collection (hr:min:sec)	Depth (m)	Organic N (mg N/l)	Ammonium* (mg N/l)	Nitrate (mg N/l)
15:10:30	2	-	< 0.05	-
15:11:00	8	-	< 0.05	-
15:11:45	16	0.27	< 0.05	0.08
15:16:45	2	0.47	< 0.05	-
15:17:30	8	0.43	< 0.05	0.11
15:18:30	16	0.74	< 0.05	0.09
15:23:00	2	-	< 0.05	-
15:23:30	8	-	< 0.05	-
15:24:30	16	-	< 0.05	-
15:28:45	2	-	< 0.05	-
15:29:30	8	-	< 0.05	-
15:30:15	16	-	< 0.05	-
15:36:30	2	-	< 0.05	-
15:37:45	8	-	< 0.05	-

\*For this and subsequent disposal operations, the analytical detection limit for ammonium was adjusted to <0.05 mg N/l. For further discussion, see Part III.

Dash (-) indicates no analysis made.

Figure IV-16  
Ammonium concentrations in bottom waters  
Galveston Dump No. 5 near Buoy D  
August 29, 1975

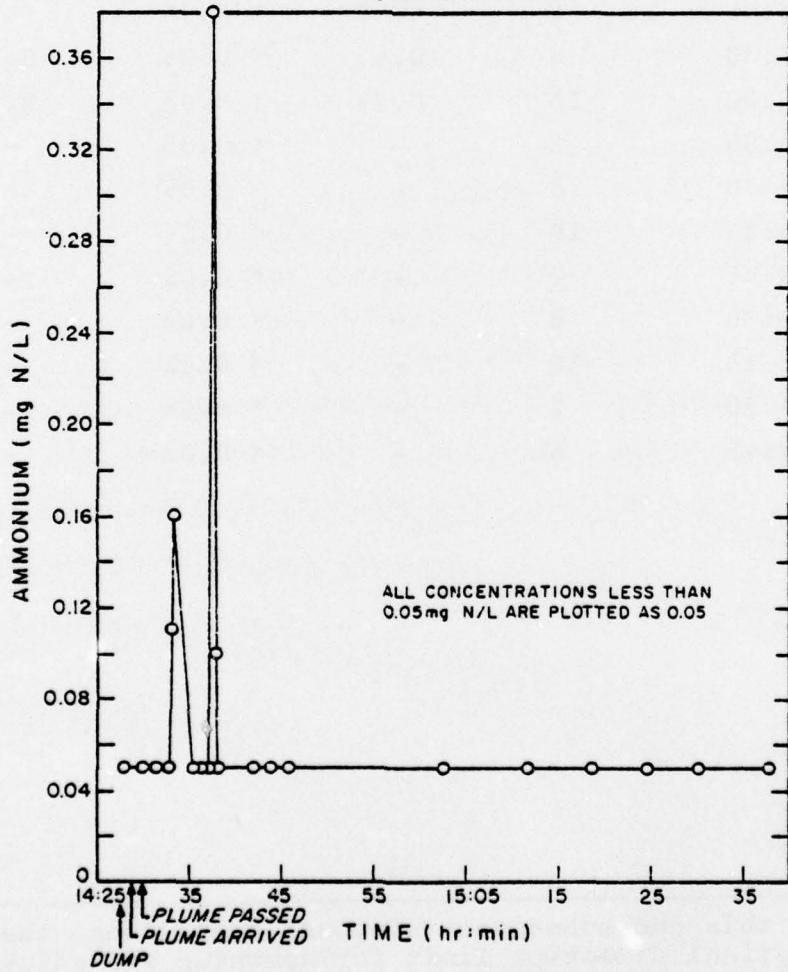


Figure IV-17  
Nitrate concentrations  
Galveston Dump No. 5 near Buoy D  
August 29, 1975

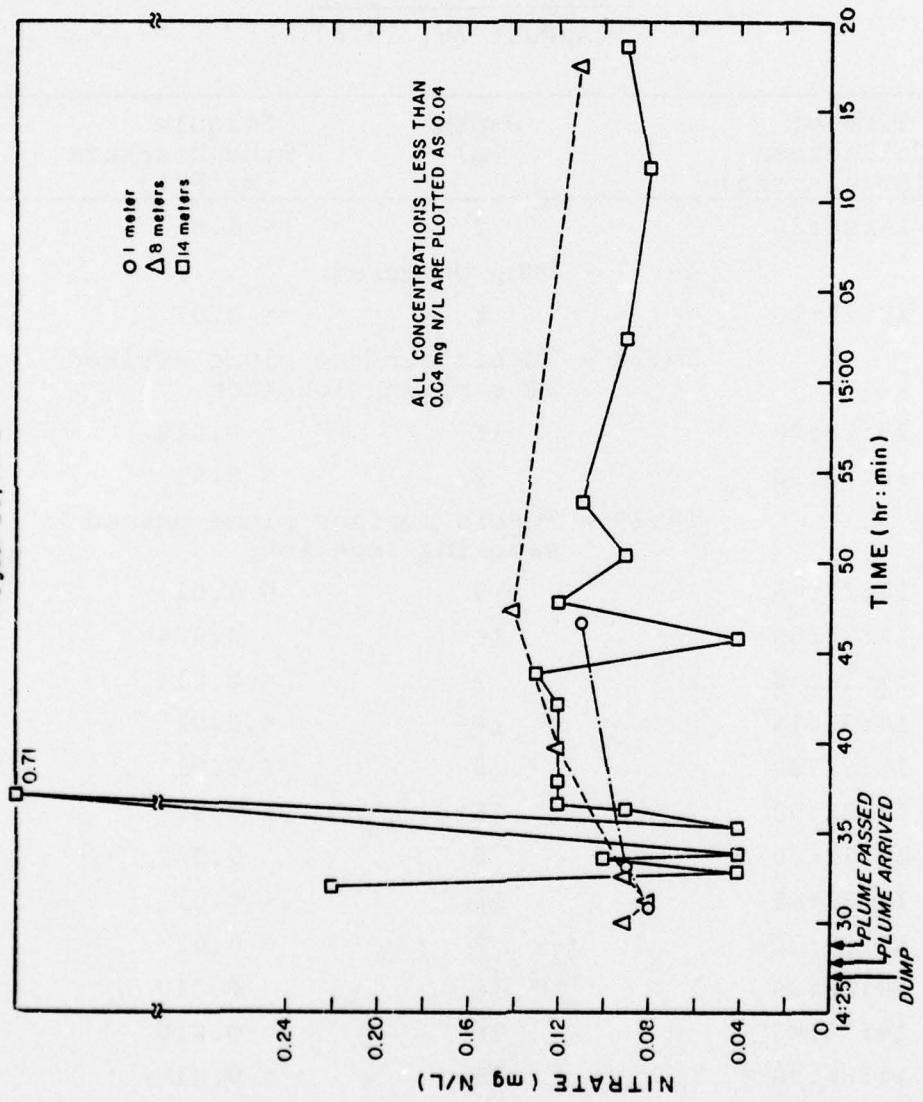


Table IV-48

Soluble Orthophosphate Concentrations: Galveston  
Dump No. 5 near Buoy D, Dredged Material from  
Galveston Bay Entrance Channel  
Buoys 1 through 3  
 (August 29, 1975)

Time of Collection (hr:min:sec)	Depth (m)	Soluble Orthophosphate (mg P/l)
14:26:30	2	< 0.01
	14:27 - Dump occurred.	
14:27:00	8	< 0.01
	14:28 - Turbid surface plume arrived at sampling location.	
14:28:00	16	0.018
14:28:30	2	< 0.01
	14:29 - Turbid surface plume passed sampling location.	
14:29:45	8	< 0.01
14:30:30	16	0.024
14:30:45	2	< 0.01
14:31:15	16	< 0.01
14:31:30	8	< 0.01
14:32:00	16	< 0.01
14:32:30	8	0.012
14:32:45	16	< 0.01
14:33:00	2	< 0.01
14:33:30	16	0.010
14:33:45	16	0.010
14:34:30	16	< 0.01
14:35:15	16	< 0.01
14:35:30	16	0.018
14:36:15	16	0.014

(Continued)

Table IV-48 (Concluded)

Time of Collection (hr:min:sec)	Depth (m)	Soluble Orthophosphate (mg P/l)
14:36:30	16	< 0.01
14:37:00	16	0.128
14:37:30	8	0.020
14:37:45	16	< 0.01
14:39:45	8	0.015
14:40:20	16	0.018
14:42:00	16	0.038
14:43:45	16	< 0.01
14:45:45	16	< 0.01
14:46:30	2	< 0.01
14:47:15	8	0.013
14:47:45	16	0.056
14:50:15	16	0.017
14:53:15	16	0.018
15:02:15	16	< 0.01
15:11:45	16	0.017
15:16:45	2	0.011
15:17:30	8	0.011
15:18:30	16	0.011

Concentrations based on one analysis of one sample.

doubled, but they returned to ambient levels within 10 minutes. The soluble ortho P concentrations near the bottom followed a somewhat irregular pattern, showing two maxima. Concentrations were just slightly above ambient and then increased 12-fold. Rapid recovery to ambient was followed by a 5.5-fold increase and another recovery to ambient about 10 minutes later.

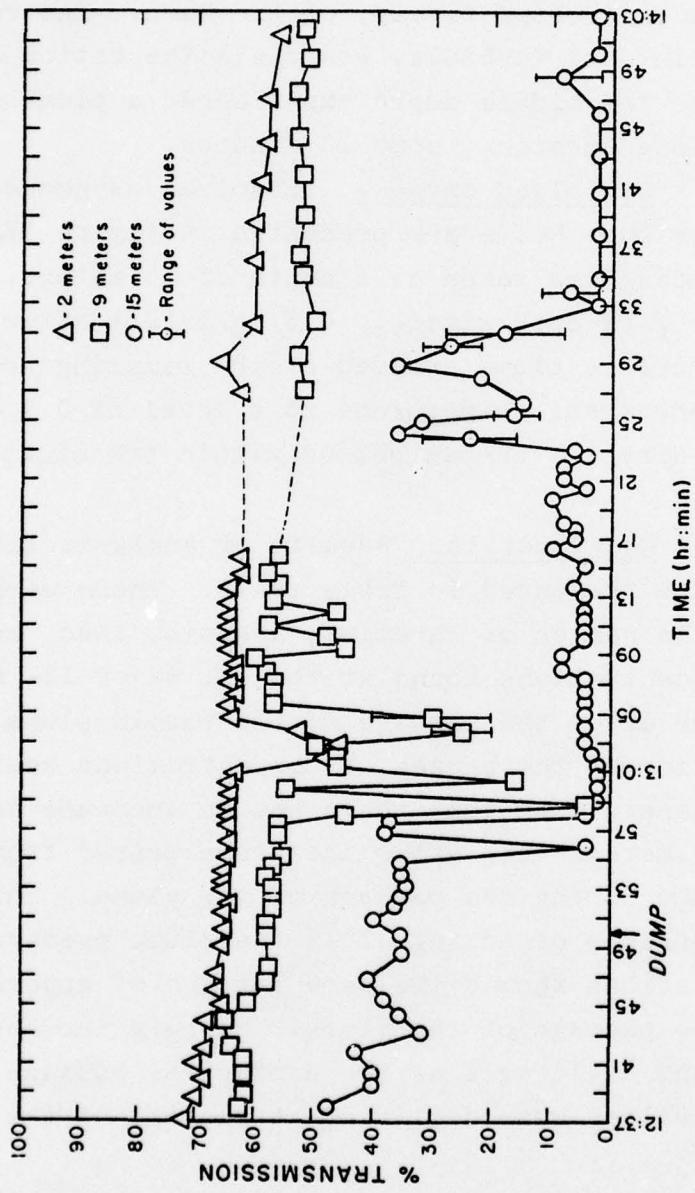
Organic carbon, oil and grease. In the fifth dump soluble TOC concentrations were 15.4, 28.3 and 15.3 mg/l before, during and after the turbid plume passage, respectively. The concentrations of TOC in the fifth dump were 19.8, 32.6 and 16.2 mg/l, respectively. Soluble oil and grease was less than the detection limit of 0.5 mg/l.

#### Galveston Dump No. 6

The next disposal operation monitored was on September 9, 1975. The dump took place at 12:50 with the turbid surface plume arriving at 13:02 and passing at 13:04. Material dredged from GBEC Buoys 3 through 7A was dumped near Buoy D at 12:50. The seas were estimated at 2 to 4 feet, and the wind was 15 miles per hour from the south. The temperature was 30°C; the water column depth was 15 meters. The sampling boat was positioned 300 meters, azimuth 270° from the buoy. Approximately 1521 cubic yards of material was dumped between the buoy and the sampling vessel, which were some 240 meters apart. The surface current had a velocity of 1.2 knots (62 cm/sec) and a direction of azimuth 270°. The bottom currents were 0.3 knots (15 cm/sec) and a direction of azimuth 235°.

Optical properties. Figure IV-18 shows the percent transmission during Galveston Dump No. 6. Percent transmission was measured at 2 meters (surface), 9 meters (middle) and 15 meters (bottom). The presence of suspended

Figure IV-18  
 Percent transmission  
 Galveston Dump No. 6 near Buoy D  
 Dredged material from Galveston Bay Entrance Channel Buoys 3-7A  
 September 9, 1975



dredged material in the surface, middle and bottom depths was first observed within 11.57 minutes, 8.08 minutes and 5.67 minutes, respectively, of the dump. The region of most intense turbidity was again the bottom although this time the middle depth experienced a plume of relatively long duration, some 13 minutes.

Dissolved oxygen. Dissolved oxygen concentrations for Dump No. 6 are presented in Figure IV-19. The D.O. reading was taken at a depth of 15 meters. There was a drop of approximately 0.5 mg/l just after the turbid surface plume arrived at the sampling boat. The D.O. concentrations returned to a level of 0.1 mg/l below the pre-disposal concentration within ten minutes of the dump.

Heavy metals. Results of analysis for heavy metals are presented in Table IV-49. There were no changes in ranges of chromium, arsenic, lead, copper and zinc concentrations found at the 1-, 9- or 15- meter depth during or after the passage of the turbid plume. Further examination of the ranges of concentrations seen for nickel and manganese show that there was an increase in the levels of these metals seen after the plume passed from those seen before and during the passage of the plume. This may be due to effects of mixing after the plume passage. Cadmium concentrations showed the same pattern of apparent release after the passage of the plume. Mercury increased 0.006  $\mu\text{g}/\text{l}$  at 1 m and 0.016  $\mu\text{g}/\text{l}$  at 9 m during the passage of the plume. Mercury values were declining at the end of the sampling period.

Nitrogen compounds. Ammonium data are presented in Table IV-50. Ammonium concentrations for all samples processed from Dump No. 6 were below the detection limit of 0.05 mg N/l.

Figure IV-19  
Dissolved oxygen concentrations  
Galveston Dump No. 6 near Buoy D - Depth 15 m  
Dredged material from Galveston Bay Entrance Channel Buoys 3-7A  
September 9, 1975

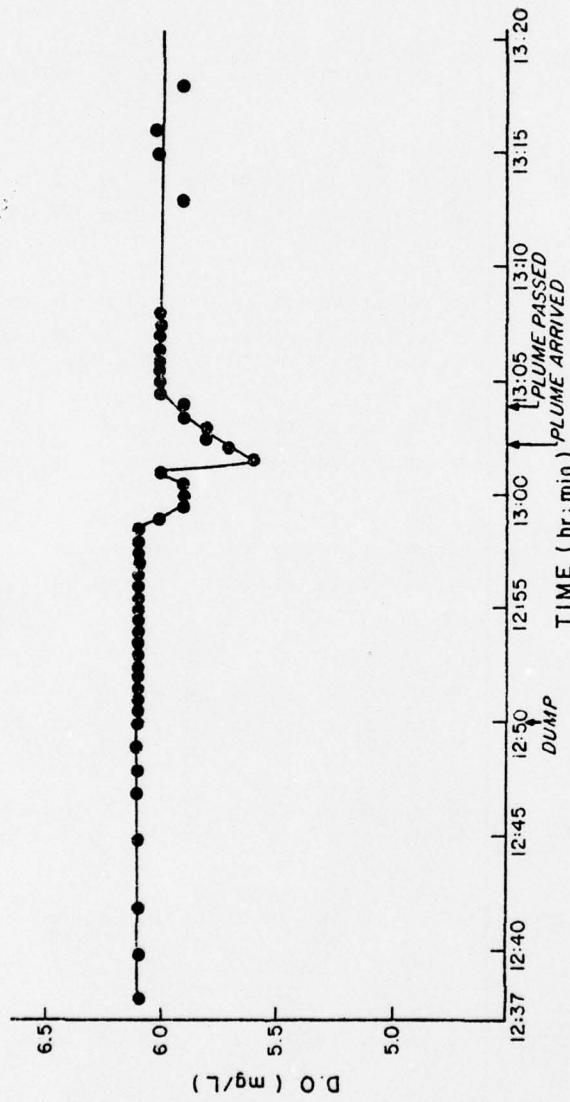


Table IV-49

Soluble Heavy Metal Concentrations: Galveston Dump No. 6 near Buoy D, Dredged Material from Galveston Bay											
Entrance Channel Buoys 3 through 7A (September 9, 1975) ( $\mu\text{g}/\text{l}$ )											
Time of Collection (hr:min:sec)	Depth (m)	Mn	Cr	Cd	Ni	Pb	Zn	Cu	Fe	Hg	As
11:41:00	1	5	<2	<0.5	2.7	3.6	4.4	5.0	40	0.016	<2
11:42:00	9	42	<2	0.8	5.8	4.8	5.7	2.4	22	0.013	<2
11:42:30	15	< 5	<2	<0.5	2.3	3.6	1.6	30.0*	29	0.015	<2
12:38:30	1	12	<2	0.5	2.7	3.6	1.6	25.0*	35	0.015	<2
12:39:00	9	5	<2	<0.5	2.0	1.8	2.9	4.1	16	0.005	<2
12:39:30	15	5	<2	0.5	3.0	4.3	14.7	2.2	50	0.013	<2
12:50:15	1	< 5	<2	<0.5	3.0	3.6	11.3	3.7	18	0.016	<2
12:50:30	9	18	<2	<0.5	3.7	4.5	5.6	4.1	51	0.013	<2
12:50:45	15	18	<2	<0.5	3.0	4.5	5.8	5.0	38	0.016	<2
12:55:45	15	5	<2	<0.5	2.7	6.3	1.3	3.6	46	0.013	<2
12:59:50	9	< 5	<2	<0.5	2.6	4.3	13.8	2.4	40	0.013	<2
13:00:15	15	< 5	<2	<0.5	3.4	3.6	9.3	5.0	151*	0.016	<2
13:00:30	1	5	<2	0.5	2.0	2.7	1.8	4.8	46	0.019	<2
13:00:45	9	< 5	<2	<0.5	1.8	3.6	9.0	4.0	22	0.017	<2
13:01:15	15	< 5	<2	<0.5	5.4	2.9	15.6	3.0	77	0.014	<2
13:02:00	1	12	<2	<0.5	3.3	4.5	4.6	5.5	11	0.017	<2

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(Continued)

Table IV-49 (Continued)

Time of Collection (hr:min:sec)	Depth (m)	Mn	Cr	Cd	Ni	Pb	Zn	Cu	Fe	Hg	As
13:02:15	9	<5	<2	<0.5	3.0	2.9	7.0	5.0	25	0.021	<2
13:02:45	1	<5	<2	<0.5	2.2	2.1	6.5	1.2	21	0.014	<2
13:03:30	1	<5	<2	<0.5	2.6	3.6	6.3	2.5	17	0.021	<2
13:03:45	9	5	<2	<0.5	3.3	4.5	5.6	4.7	29	0.012	<2
13:04 - Turbid surface plume passed sampling location.											
13:04:00	15	12	<2	<0.5	4.7	1.8	20.7	5.0	22	0.010	<2
13:04:30	1	<5	<2	<0.5	3.0	3.6	14.3	2.0	18	0.017	<2
13:05:15	9	42	<2	1.2	5.8	4.1	5.5	2.7	19	0.001	<2
13:05:55	1	33	<2	1.1	5.5	4.8	6.5	2.6	22	0.001	<2
13:06:50	150*	<2	0.8	6.5	3.3	5.4	2.2	2.2	0.001	<2	
13:08:10	9	42	<2	1.1	6.5	4.1	9.7	2.4	17	0.001	<2
13:10:00	9	42	<2	1.0	4.8	4.1	11.4	2.3	16	0.001	<2
13:10:45	1	42	<2	2.4	10.2	4.8	9.8	68.1*	21	0.007	<2
13:13:45	9	33	<2	1.2	6.5	3.3	8.2	2.6	282*	0.001	<2
13:13:45	15	33	<2	1.0	7.8	2.6	4.4	2.4	17	0.001	<2
13:15:00	1	50	<2	1.2	5.5	3.3	4.4	2.4	11	0.003	<2
13:15:20	9	25	<2	1.0	5.8	2.6	10.7	2.8	14	0.003	<2

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(Continued)

Table IV-49 (Concluded)

Time of Collection (hr:min:sec)	Depth (m)	Mn	Cr	Cd	Ni	Pb	Zn	Cu	Fe	Hg	As
13:15:35	15	33	<2	1.0	6.8	2.6	7.9	2.7	27	0.024	<2
13:21:15	15	58	<2	0.8	4.8	2.6	5.7	2.4	26	0.003	<2
13:30:30	1	50	<2	1.1	5.8	2.6	5.3	2.3	11	0.006	<2
13:31:00	9	25	<2	1.1	6.2	3.3	4.8	2.2	22	0.018	<2
13:31:35	15	50	<2	1.0	6.2	2.6	4.3	2.2	22	0.003	<2
14:16:15	1	58	<2	1.1	4.5	4.1	5.9	6.4	42	0.003	<2
14:16:30	9	33	<2	0.9	4.5	2.6	8.6	2.7	57	0.003	<2
14:16:45	15	50	<2	0.5	5.8	2.6	6.4	2.2	36	0.012	<2

\* There were unusually high values of copper encountered at 11:42:30, 12:38:30 and 13:10:45, ranging from 25 to 68  $\mu\text{g}/\text{l}$ . Two high values of iron, 151  $\mu\text{g}/\text{l}$  at 13:00:15 and 282  $\mu\text{g}/\text{l}$  at 13:13:45 were seen. One manganese value of 150  $\mu\text{g}/\text{l}$  at 13:06:50 was also quite high. These high values do not correlate with depth (i.e., they are not all bottom samples), and it is thought that they are probably due to analytical error or sample contamination.

Table IV-50  
Ammonium Concentrations: Galveston Dump No. 6  
near Buoy D, Dredged Material from  
Galveston Bay Entrance Channel  
Buoys 3 through 7A  
(September 9, 1975)

Time of Collection (hr:min:sec)	Depth (m)	Ammonium (mg N/l)
11:41:00	1	< 0.05
11:42:00	9	< 0.05
11:42:30	15	< 0.05
12:38:30	1	< 0.05
12:39:00	9	-
12:39:30	15	< 0.05
12:50 - Dump occurred.		
12:50:15	1	< 0.05
12:50:30	9	-
12:50:45	15	< 0.05
12:55:45	15	< 0.05
12:59:50	9	< 0.05
13:00:15	15	< 0.05
13:00:30	1	< 0.05
13:00:45	9	< 0.05
13:01:15	15	< 0.05
13:02 - Turbid surface plume arrived at sampling location.		
13:02:00	1	< 0.05
13:02:15	9	< 0.05
13:02:45	1	< 0.05
13:03:30	1	< 0.05
13:03:45	9	< 0.05
13:04:00	15	< 0.05

(Continued)

Table IV-50 (Concluded)

Time of Collection (hr:min:sec)	Depth (m)	Ammonium (mg N/l)
	13:04 - Turbid surface plume passed sampling location.	
13:04:30	1	< 0.05
13:05:15	9	< 0.05
13:05:55	1	< 0.05
13:06:50	15	< 0.05
13:08:10	9	< 0.05
13:10:00	9	< 0.05
13:10:15	1	< 0.05
13:13:45	9	< 0.05
13:13:45	15	< 0.05
13:15:00	1	< 0.05
13:15:20	9	< 0.05
13:15:35	15	< 0.05
13:21:15	15	< 0.05
13:30:30	1	< 0.05
13:31:00	9	< 0.05
13:31:35	15	< 0.05
13:40:00	9	< 0.05
13:40:35	15	< 0.05
14:16:15	1	< 0.05
14:16:30	9	< 0.05
14:16:45	15	< 0.05

Phosphorus compounds. Concentrations of soluble ortho P are presented in Table IV-51. Soluble ortho P concentrations appeared to increase at all three depths, but the increases did not appear to be as great as those found during the previous disposal operations near Buoy D. Ambient soluble ortho P concentrations in the surface water were

Table IV-51

Soluble Orthophosphate Concentrations: Galveston  
Dump No. 6 near Buoy D, Dredged Material from  
Galveston Bay Entrance Channel  
Buoys 3 through 7A  
 (September 9, 1975)

Time of Collection	Depth (m)	Soluble Orthophosphate (mg P/l)	
		$\bar{X}$	SD
11:41:00	1	< 0.01	~ 0
11:42:00	9	0.015	0
11:42:30	15	< 0.01	~ 0
12:38:30	1	0.012	0.001
12:39:00	9	0.018	0.001
12:39:30	15	0.013	0
12:50 - Dump occurred.			
12:50:15	1	0.01	0.001
12:50:30	9	< 0.01	~ 0
12:50:45	15	< 0.01	~0.003
12:55:45	15	< 0.01	~0.001
12:59:50	9	< 0.01	~ 0
13:00:15	15	0.023	0
13:00:30	1	0.013	0.001
13:00:45	9	< 0.01	~ 0
13:01:15	15	0.019	0.001
13:02 - Turbid surface plume arrived at sampling location.			
13:02:00	1	< 0.01	0.001
13:02:15	9	0.012	0
13:02:45	1	0.011	0.002
13:03:30	1	< 0.01	0.001
13:03:45	9	< 0.01	~0.001
13:04 - Turbid surface plume passed sampling location.			

(Continued)

Table IV-51 (Concluded)

Time of Collection (hr:min:sec)	Depth (m)	Soluble Orthophosphate (mg P/l)	
		$\bar{X}$	SD
13:04:00	15	< 0.01	~ 0.001
13:04:30	1	< 0.01	~ 0.001
13:05:15	9	< 0.01	~ 0
13:05:55	1	0.012	0
13:06:50	15	0.022	0.001
13:08:10	9	0.013	0.001
13:10:00	9	0.018	0.001
13:10:15	1	< 0.01	~ 0
13:13:45	9	0.022	0
13:13:45	15	0.024	0.002
13:15:00	1	0.022	0
13:15:20	9	0.015	0.001
13:15:35	15	< 0.01	~ 0
13:21:15	15	0.020	0.001
13:30:30	1	0.014	0
13:31:00	9	0.018	0.001
13:31:35	15	0.023	0.001
13:40:00	9	< 0.01	~ 0
13:40:35	15	0.02	0
14:16:15	1	0.016	0.001
14:16:30	9	< 0.01	~ 0.001
14:16:45	15	0.011	0

Mean and standard deviations calculated from duplicate analyses of one sample.

between <0.01 mg P/l (detection limit) and 0.012 mg P/l. During the passage of the turbid surface plume, the concentrations did not rise above this level. The sample taken 11 minutes after the plume passed showed an approximately two-fold increase (to 0.022 mg P/l) over ambient soluble ortho P concentrations. A sample taken 15 minutes later showed a decrease in concentration to 0.014 mg P/l. About 45 minutes later, the concentration was slightly above ambient levels (0.016 mg P/l).

Soluble ortho P concentrations at mid-depth (9 m) varied between <0.01 mg P/l (detection limit) and 0.019 mg P/l before arrival of the turbid plume. When the mid-depth percent light transmission was lowest, the soluble ortho P concentration was <0.01 mg P/l (detection limit). It then appeared to rise steadily to 0.022 mg P/l about 14 minutes later. About 25 minutes after the apparent maximum, the soluble ortho P concentrations had returned to ambient levels.

As the percent light transmission in the near bottom waters dropped to 1 percent, the soluble ortho P increased from <0.01 to 0.023 mg P/l. It dropped back to ambient levels about 4 minutes later, and fluctuated between <0.01 and 0.024 mg P/l for the duration of the sampling period.

#### Galveston Dump No. 7

The atmospheric and sea conditions of the seventh dump were the same as in Galveston Dump No. 6, which also occurred September 9. The dredged material also came from Buoys 3 through 7A in the GBEC. The location of the sampling vessel was also identical. This time, however, the dredge opened its doors early (at 14:09) about 75 to 100 meters before crossing the imaginary line between the buoy and the sampling boat. The surface turbid plume, which was very localized, did not pass beneath the

sampling boat. The plume could be visually sighted from the sampling vessel but was not close enough to be detected with the instruments. Samples taken from this dump were saved and analyzed. Approximately 1426 cubic yards of material was disposed of during this operation.

Optical properties. The turbidity data for Dump No. 7 are presented in Figure IV-20. A point of interest in this graph is the transmissometer readings at 15 meters. The bottom depth at Buoy D was turbid up to and after the seventh dump. This suggests the possibility that the bottom waters were still being affected by the material that had been dumped at 12:50 (Galveston Dump No. 6).

Dissolved oxygen. Dissolved oxygen readings for Galveston Dump No. 7 were taken at a depth of 14 meters (Table IV-52). Examination of this table shows that there was no significant drop in D.O. during the monitoring period.

Heavy metals. Heavy metals data in Table IV-53 indicate manganese release but only in bottom waters. Concentrations observed were on the order of 20 to 30  $\mu\text{g/l}$ . Concentrations within the plume from Dump No. 6 ranged from 40 to 150  $\mu\text{g/l}$ . It appears that the elevated concentrations of manganese noted at Dump No. 7 in the bottom waters may be due to the spread of the bottom plume from this dump. It is also possible that these elevated concentrations are residual effects arising from Dump No. 6. The data taken outside the plume from Dump No. 7 show no observable effects on concentrations of other metals measured.

Nitrogen compounds. The ammonium data which is presented in Table IV-54 show that ammonium concentrations

**Figure IV-20**  
 Percent transmission  
 Galveston Dump No. 7 near Buoy D  
 Dredged material from Galveston Bay Entrance Channel Buoys 3-7A  
 September 9, 1975

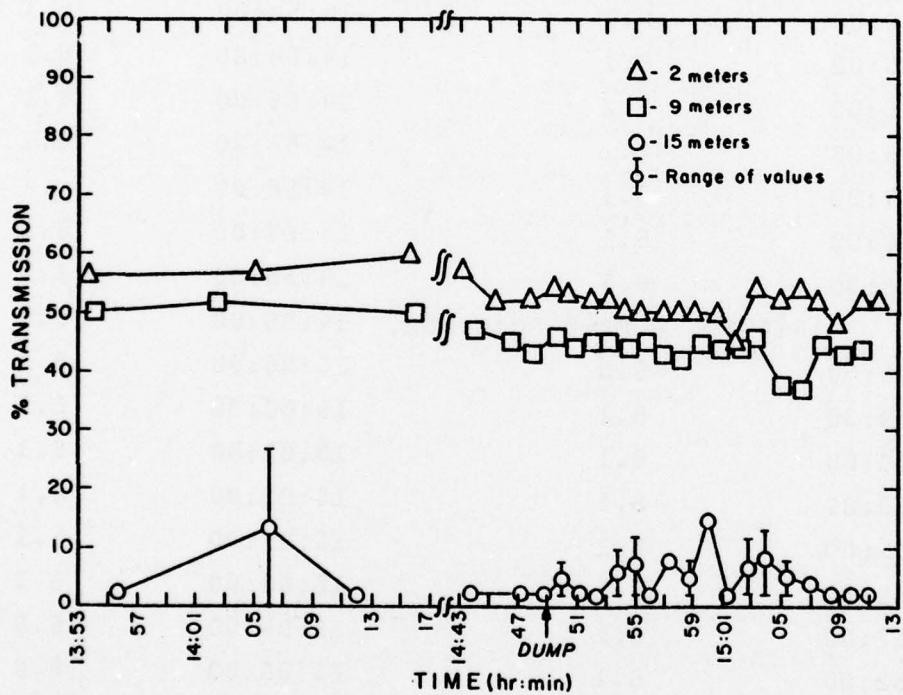


Table IV-52  
Dissolved Oxygen Concentrations: Galveston Dump No. 7  
near Buoy D\*, Dredged Material from Galveston  
Bay Entrance Channel Buoys 3 through 7A  
(September 9, 1975)

Time of Collection (hr:min:sec)	D.O. (mg/l)	Time of Collection (hr:min:sec)	D.O. (mg/l)
14:20:00	6.2	14:54:00	6.1
14:35:00	6.1	14:54:30	6.1
14:45:00	6.2	14:55:00	6.1
14:46:00	6.1	14:55:30	6.1
14:47:00	6.1	14:56:00	6.1
14:48:00	6.1	14:57:00	6.1
14:48:30	6.1	14:58:00	6.1
14:49:00 - Dump Occurred.		14:59:00	6.1
14:49:00	6.0	15:00:00	6.1
14:49:30	6.1	15:00:30	6.1
14:50:00	6.1	15:01:00	6.1
14:50:30	6.1	15:01:30	6.1
14:51:00	6.1	15:02:00	6.1
14:51:30	6.1	15:03:00	6.1
14:52:00	6.1	15:04:00	6.0
14:52:30	6.1	15:05:00	6.0
14:53:00	6.1	15:10:00	6.1
14:53:30	6.1		

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\*Depth - 14 m.

Soluble Heavy Metal Concentrations: Galveston Dump No. 7  
 near Buoy D, Dredged Material from Galveston Bay  
Entrance Channel Buoys 3 through 7A  
 (September 9, 1975)  
 ( $\mu\text{g}/\text{l}$ )

Time of Collection (hr:min:sec)	Depth (m)	Mn	Cr	Cd	Ni	Pb	Zn	Cu	Fe	Hg	As
14:47:30	1	8	< 2	1.6	5.5	1.5	5.3	3.9	37	0.003	< 2
14:48:00	9	6	< 2	1.7	5.0	1.5	1.2	2.1	27	0.003	< 2
14:48:45	15	< 5	< 2	1.6	6.0	1.5	1.4	2.8	58	0.006	< 2
				14:49 - Dump occurred.*							
14:53:00	1	10	< 2	1.9	4.8	1.5	5.3	3.6	28	0.003	< 2
14:53:30	9	6	< 2	1.7	6.3	1.9	1.3	2.7	38	0.003	< 2
14:53:45	15	6	< 2	1.9	5.3	1.5	4.9	2.3	35	0.003	< 2
14:59:45	1	8	< 2	1.5	5.5	1.5	1.3	3.5	48	<0.001	< 2
15:00:00	9	31	< 2	1.7	5.3	1.2	2.3	9.0	27	0.003	< 2
15:00:10	15	29	< 2	1.6	5.5	1.9	2.3	9.5	38	0.006	< 2
15:01:15	1	8	< 2	1.8	5.5	1.2	2.3	3.1	25	0.003	< 2
15:02:00	1	8	< 2	1.5	5.5	1.5	1.3	3.1	27	0.003	< 2
15:04:50	9	6	< 2	2.0	5.3	2.3	1.3	3.0	37	<0.001	< 2
15:06:35	9	25	< 2	1.6	5.5	1.5	1.4	8.9	33	<0.001	< 2
15:08:30	1	27	< 2	1.6	6.0	1.9	2.0	8.7	35	0.003	< 2
15:08:50	9	19	< 2	1.5	5.3	1.5	2.2	6.2	30	0.003	< 2
15:09:15	15	8	< 2	1.7	5.3	1.5	2.8	2.4	33	0.003	< 2

\*Turbid surface plume missed sampling location by approximately 100 meters.

Table IV- 54  
Ammonium Concentrations: Galveston Dump No. 7  
near Buoy D, Dredged Material from  
Galveston Bay Entrance Channel  
Buoys 3 through 7A  
(September 9, 1975)

Time of Collection (hr:min:sec)	Depth (m)	Ammonium (mg N/l)
14:47:30	1	<0.05
14:48:00	9	<0.05
14:48:45	15	<0.05
	14:49 - Dump occurred.	
14:53:00	1	<0.05
14:53:30	9	<0.05
14:53:45	15	<0.05
14:49:45	1	<0.05
15:00:00	9	<0.05
15:00:10	15	<0.05
15:00:45	9	<0.05
15:01:15	1	<0.05
15:02:00	1	<0.05
15:04:50	9	<0.05
15:05:00	15	<0.05
15:06:35	9	<0.05
15:08:30	1	<0.05
15:08:50	9	<0.05
15:09:15	15	<0.05

for all samples processed for Dump No. 7 were found to be below the detection limit of 0.05 mg N/l.

Phosphorus compounds. The concentrations of soluble ortho P are presented in Table IV-55. Before disposal, soluble ortho P concentrations were below the detection limit. Approximately 11 minutes after disposal, they rose to 0.14 mg P/l. Approximately two minutes later, the concentrations returned to ambient levels. At mid-depth (9 m), the soluble ortho P level dropped slightly (from 0.013 mg P/l before disposal to 0.01 mg P/l) and remained at that level for about seven minutes. Approximately six minutes later, the concentration rose to 0.019 mg P/l but dropped to 0.01 mg P/l in another two minutes.

Comparison of Tables IV-51 and IV-55 shows that during Galveston Dump No. 7 soluble ortho P concentrations appear to be of the same magnitude as those found during the sixth dump. Changes in the surface and bottom concentrations during Dump No. 7 appear to be smaller than those in the previous disposal. This indicates that the release of soluble ortho P during dredged material disposal was localized in the turbid plume.

#### Texas City Channel Turning Basin Dump No. 1

Material dredged from the TCCTB was disposed of at a temporary buoy, Buoy B<sub>1</sub> (located about 500 meters seaward from Buoy B) on October 9, 1975, at 16:45. Disposal of 765 cubic yards of TCCTB material was monitored. The sampling vessel waited until the dump occurred, then moved into the surface turbid plume to collect samples and began sampling 300 meters seaward of Buoy B<sub>1</sub>. The sample boat drifted along with the turbid surface plume.

Table IV-55  
Soluble Orthophosphate Concentrations: Galveston  
Dump No. 7 near Buoy D, Dredged Material from  
Galveston Bay Entrance Channel  
(September 9, 1975)

Time of Collection (hr:min:sec)	Depth (m)	Soluble Orthophosphate (mg P/l) $\bar{x}$	SD
14:47:30	1	<0.01	~ 0
14:48:00	9	0.013	0
14:48:45	15	0.016	0
14:49:00 - Dump occurred.			
14:53:00	1	<0.01	~0.001
14:53:30	9	0.01	0.001
14:53:45	15	0.01	0
14:59:45	1	0.014	0.001
15:00:00	9	-	-
15:00:10	15	0.01	0.001
15:00:45	9	<0.01	~0.001
15:01:15	1	0.013	0.001
15:02:00	1	0.01	0
15:04:50	9	0.014	0.001
15:05:00	15	0.014	0
15:06:35	9	0.019	0.001
15:08:30	1	<0.01	~ 0
15:08:50	9	0.01	0.001
15:09:15	15	0.012	0.001

Mean and standard deviation are calculated from duplicate analyses of one sample.

Dash (-) indicates analysis not performed.

Optical properties. Figure IV-21 presents percent transmission data from Texas City Dump No. 1. The figure shows that the turbid plume was found at 2 and 10 meters, but not at the 7-meter depth. The absence of a mid-depth plume is not explainable at this time. The extended surface turbidity (20 minutes) observed in this disposal operation as well as the variable bottom turbidity is undoubtedly due to the drifting of the boat during sampling.

Dissolved oxygen. Dissolved oxygen readings were taken at 2 and 11 meters (Table IV-56). There was no significant drop found in the D.O. concentrations at either depth.

Heavy metals. The only heavy metal analyzed for samples from Texas City Dump No. 1 was manganese. These samples had been stored for four months at 4°C. Since manganese is the only metal of concern found to be released in these operations, the samples were analyzed for manganese to see if any trends of release might be found, even after storage. The data in Table IV-57 show that manganese values for samples from Texas City Dump No. 1 ranged from 17 to 86 µg/l. The highest values were observed in samples taken at 8 and 11 meters during the first three minutes of the turbid surface plume passage. Afterwards soluble manganese decreased slightly. There was a release of soluble manganese during the first 12 to 14 minutes that the plume was sampled. Concentrations of samples taken in the plume during this time were 19 to 86 µg/l. Concentrations found after the plume had drifted past the sampling vessel ranged from 17 to 42 µg/l manganese.

Figure IV-21  
 Percent transmission  
 Texas City Dump No 1 near Buoy B,  
 Dredged material from Texas City Channel Turning Basin  
 October 9, 1975

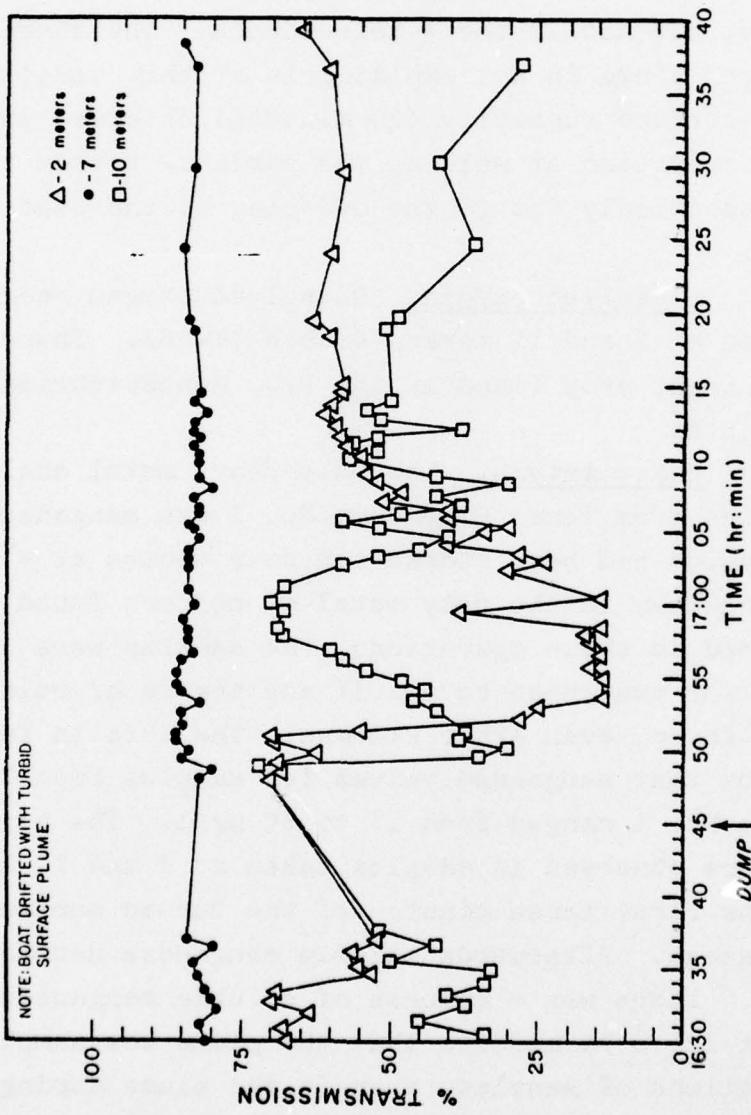


Table IV-56

Dissolved Oxygen Concentrations: Texas City  
Dump No. 1 near Buoy B<sub>1</sub>, Dredged Material  
from Texas City Channel Turning Basin

(October 9, 1975)

Time (hr:min:sec)	Depth (m)	D.O. (mg/l)
16:30:00	2	7.1
16:30:00	10	6.3
16:37:00	12	6.4
	16:45:00 - Dump occurred.	
	16:50:00 - Sampling vessel moved into turbid surface plume.	
16:53:00	11	6.5
16:54:00	11	6.5
16:55:00	11	6.5
16:56:00	2	7.1
16:57:00	11	6.5
16:58:00	11	6.4
16:59:00	11	6.4
17:00:00	2	7.5
17:01:00	2	7.5
17:02:00	2	7.6
17:03:00	2	7.6
17:04:00	2	7.5
17:08:00	11	6.6
17:11:00	11	6.5
17:12:00	11	6.4
	17:13:00 - Turbid surface plume passed drifting sampling vessel.	

Nitrogen compounds. The ammonium data presented in Table IV-58 show that except for four surface samples and one mid-depth sample (all 0.10 mg N/l or less), all water samples collected had ammonium concentrations below the 0.05 mg N/l detection limit.

Phosphorus compounds. Soluble ortho P concentrations are presented in Table IV-59. (The analyses were made approximately four months after collection.) While the sampling boat was in the turbid surface plume, soluble ortho P levels near surface varied erratically from 0.036 to 0.086 mg P/l.

Table IV-57  
Soluble Manganese Concentrations:\* Texas City Dump  
No. 1 near Buoy B<sub>1</sub>, Dredged Material from Texas  
City Channel Turning Basin  
(October 9, 1975)

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Time of Collection (hr:min:sec)	Depth (m)	Soluble Manganese ( $\mu\text{g/l}$ )
16:45:00 - Dump occurred.		
16:50:00 - Sampling vessel moved into turbid surface plume.		
16:50:00	1	50
16:50:15	8	58
16:50:25	11	58
16:52:00	8	50
16:52:15	11	75
16:52:40	1	67
16:53:00	11	67
16:53:20	1	67
16:53:30	8	75
16:53:45	11	19
15:54:00	1	67
16:54:15	8	53
16:54:30	11	33
16:54:45	1	69
16:55:00	8	58
16:55:10	11	42
16:55:30	1	36
16:55:40	8	53
16:56:00	11	69
16:56:15	1	69
16:56:30	8	53

(Continued)

Table IV-57 (Continued)

Time of Collection (hr:min:sec)	Depth (m)	Soluble Manganese ( $\mu$ g/l)
16:56:45	11	19
16:57:05	1	58
16:57:15	8	75
16:57:40	11	33
16:58:15	1	69
16:58:25	8	36
16:58:45	1	53
16:59:00	8	58
16:59:15	11	33
16:59:35	1	67
17:00:20	1	58
17:00:35	8	50
17:00:55	11	25
17:02:00	1	53
17:02:30	8	53
17:02:45	11	86
17:03:00	1	69
17:03:35	8	86
17:04:20	11	19
17:04:40	1	53
17:05:00	11	19
17:05:20	1	36
17:06:00	1	17
17:06:30	8	33
17:06:40	11	42
17:09:00	11	17
17:09:15	1	50
17:10:35	8	25

(Continued)

Table IV-57 (Concluded)

Time of Collection (hr:min:sec)	Depth (m)	Soluble Manganese ( $\mu$ g/l)
17:10:50	11	17
17:11:25	1	33
17:11:45	8	25
17:12:15	11	25
17:13:00	- Turbid surface plume passed drifting sampling vessel.	
17:14:15	1	17
17:14:30	8	42
17:14:45	11	17
17:19:30	1	42
17:19:45	8	25
17:20:30	11	25
17:26:50	1	42
17:27:20	8	25
17:33:55	1	42
17:34:15	8	42
17:34:40	11	17
17:40:20	1	25
17:40:45	8	17
17:41:00	11	17

\*Samples were stored for approximately four months.  
On February 12, 1976, they were filtered and acidified according to the procedures in Part III.

Table IV- 58  
Ammonium Concentrations: Texas City Dump No. 1  
near Buoy B<sub>1</sub>, Dredged Material from Texas  
City Channel Turning Basin  
(October 9, 1975)

Time of Collection (hr:min:sec)	Depth (m)	Ammonium (mg N/l)
	16:45 - Dump occurred.	
	16:50 - Sampling vessel moved into turbid surface plume.	
16:50:00	1	<0.05
16:50:15	8	<0.05
16:50:25	11	<0.05
16:50:40	11	<0.05
16:51:00	1	<0.05
16:51:15	8	<0.05
16:51:30	11	<0.05
16:51:45	1	<0.05
16:52:00	8	<0.05
16:52:15	11	<0.05
16:52:40	1	<0.05
16:52:50	8	<0.05
16:53:00	11	<0.05
16:53:20	1	<0.05
16:53:30	8	<0.05
16:53:45	11	<0.05
16:54:00	1	<0.05
16:54:15	8	<0.05
16:54:30	11	<0.05
16:54:45	1	0.07
16:55:00	8	<0.05
16:55:10	11	<0.05
16:55:30	1	<0.05

(Continued)

Table IV- 58 (Continued)

Time of Collection (hr:min:sec)	Depth (m)	Ammonium (mg N/l)
16:55:40	8	< 0.05
16:56:00	11	< 0.05
16:56:15	1	< 0.05
16:56:30	8	< 0.05
16:56:45	11	< 0.05
16:57:05	1	< 0.05
16:57:15	8	< 0.05
16:57:40	11	< 0.05
16:58:15	1	< 0.05
16:58:25	8	< 0.05
16:58:45	1	< 0.05
16:59:00	8	< 0.05
16:59:15	11	< 0.05
16:59:35	1	< 0.05
17:00:05	8	< 0.05
17:00:20	1	0.07
17:00:35	8	< 0.05
17:00:55	11	< 0.05
17:01:20	1	< 0.05
17:01:20	1	< 0.05
17:01:45	8	< 0.05
17:02:00	1	0.05
17:02:00	1	< 0.05
17:02:30	8	< 0.05
17:02:45	11	< 0.05
17:03:00	1	< 0.05
17:03:30	1	< 0.05
17:03:35	8	0.07

(Continued)

Table IV-58 (Continued)

Time of Collection (hr:min:sec)	Depth (m)	Ammonium (mg N/l)
17:04:00	8	<0.05
17:04:20	11	<0.05
17:04:40	1	<0.05
17:05:00	11	<0.05
17:05:20	1	<0.05
17:05:55	11	<0.05
17:06:00	1	<0.05
17:06:30	8	<0.05
17:06:40	11	<0.05
17:08:00	11	<0.05
17:09:00	11	<0.05
17:09:30	11	<0.05
17:09:45	1	0.10
17:10:35	8	<0.05
17:10:50	11	<0.05
17:11:25	1	<0.05
17:11:45	8	<0.05
17:12:15	11	<0.05
17:13 - Turbid surface plume passed drifting sampling vessel.		
17:14:15	1	<0.05
17:14:30	8	<0.05
17:14:45	11	<0.05
17:19:30	1	<0.05
17:19:45	8	<0.05
17:20:30	11	<0.05
17:26:50	1	<0.05
17:27:20	8	<0.05
17:27:45	11	<0.05

(Continued)

Table IV-58 (Continued)

Time of Collection (hr:min:sec)	Depth (m)	Ammonium (mg N/l)
17:28:00	11	<0.05
17:33:55	1	<0.05
17:34:15	8	<0.05
17:34:40	11	<0.05
17:40:20	1	<0.05
17:40:45	8	<0.05
17:41:00	11	<0.05

After the ship had drifted out of the surface plume, surface concentrations were between 0.034 mg P/l and 0.051 mg P/l and were generally in the range found in the turbid surface plume. These surface concentrations were for the most part higher than those found at the other depths, although samples collected two months earlier near Buoy B had shown surface ambient soluble ortho P concentrations to be 0.01 mg P/l. The higher concentrations found during October disposal operations probably reflect the changes in the ambient levels of phosphate due to localized input from Galveston Bay.

Concentrations of soluble ortho P at mid-depth (8m) ranged from <0.01 mg P/l (detection limit) to 0.053 mg P/l. There was no apparent pattern with respect to percent light transmission. The August pre-disposal concentrations found near Buoy B at mid-depth were approximately 0.05 mg P/l; this is at the upper range of concentrations found during this disposal operation. Concentrations of soluble ortho P at 11 m fluctuated between 0.015 and 0.173 mg P/l. There was no apparent correlation with the percent light transmission.

Table IV- 59  
Soluble Orthophosphate Concentrations: Texas City  
Dump No. 1 near Buoy B<sub>1</sub>, Dredged Material from  
Texas City Channel Turning Basin  
(October 9, 1975)

Time of Collection (hr:min:sec)	Depth (m)	Soluble Orthophosphate (mg P/l)
16:45 - Dump occurred.		
16:50 - Sampling vessel moved into turbid surface plume.		
16:50:00	1	0.066
16:50:25	11	0.173
16:52:00	8	0.041
16:52:15	11	0.033
16:52:40	1	0.036
16:53:00	11	0.053
16:53:20	1	0.038
16:53:30	8	0.011
16:53:45	11	0.020
16:54:00	1	0.086
16:54:15	8	0.020
16:54:30	11	0.039
16:54:45	1	0.068
16:55:00	8	0.024
16:55:10	11	0.047
16:55:30	1	0.062
16:55:40	8	0.013
16:56:00	11	0.015
16:56:15	1	0.060
16:56:30	8	0.015
16:56:45	11	0.032

(Continued)

Table IV-59 (Continued)

Time of Collection (hr:min:sec)	Depth (m)	Soluble Orthophosphate (mg P/l)
16:57:05	1	0.036
16:57:15	8	0.027
16:57:40	11	0.025
16:58:15	1	0.04
16:58:25	8	0.032
16:58:45	1	0.056
16:59:00	8	0.053
16:59:15	11	0.032
16:59:35	1	0.057
17:00:20	1	0.062
17:00:35	8	0.050
17:00:55	11	0.030
17:02:00	1	0.054
17:02:30	8	0.020
17:02:45	11	0.022
17:03:00	1	0.070
17:03:33	8	0.034
17:04:20	11	0.039
17:04:40	1	0.054
17:05:00	11	0.023
17:05:20	1	0.047
17:06:00	1	0.045
17:06:30	8	0.026
17:06:40	11	0.034
17:09:00	11	0.021
17:00:15	1	0.047
17:10:35	8	<0.01
17:00:50	11	0.031
17:11:25	1	0.039
17:00:45	8	0.012
17:12:15	11	0.059

(Continued)

Table IV-59 (Concluded)

Time of Collection (hr:min:sec)	Depth (m)	Soluble Orthophosphate (mg P/l)
17:13:00 - Turbid surface plume passed sampling vessel.		
17:14:15	1	0.041
17:00:30	8	0.014
17:00:45	11	0.024
17:19:30	1	0.051
17:00:45	8	0.018
17:20:30	11	0.044
17:26:50	1	0.051
17:27:20	8	0.014
17:33:55	1	0.039
17:34:15	8	0.019
17:00:40	11	0.026
17:40:20	1	0.034
17:00:45	8	0.018
17:41:00	11	0.034

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Concentrations based on one analysis of one sample.

Texas City Channel Turning Basin Dump No. 2

On October 10, disposal of TCCTB material dumped at 10:13 was monitored. The turbid surface plume arrived at 10:18 and passed at 10:21. The seas were 2 to 4 feet, the wind was 10 miles per hour from the southeast, and the temperature was 24°C. The sampling boat was anchored approximately 75 meters, azimuth 50° from Buoy B<sub>1</sub>. Disposal occurred approximately 40 meters off the bow of the sampling vessel. The current readings were found to be for the surface, 0.1 knots (5 cm/sec) azimuth 50° and for the bottom, 0.2 knots (10 cm/sec) azimuth 170°. Approximately 765 cubic yards of material were dumped.

Optical properties. Figure IV-22 presents percent transmission data from the second Texas City disposal operation. The suspended material was present at each depth monitored; the turbid plumes took 4, 5 and 3 minutes to reach the sampling vessel at surface, mid- and bottom depths, respectively. The data indicate that the turbid conditions at the 2- and 7-meter depths were short-lived--2 and 5 minutes, respectively. The turbid conditions at the 10-meter depth persisted for over an hour, with only gradual increases in percent transmission 16 minutes after the dump. Secchi depths were recorded prior to the disposal operation (at 9:22) October 10, 1975, and 22 minutes after Texas City Dump No. 2. The initial Secchi depth was 3.0 meters; after disposal it was 2.5 meters.

Dissolved oxygen. Figure IV-23 shows a decrease at 2 and 10 meters in D.O. levels just after the second Texas City dump. At the other depths there is no detectable change in D.O. levels. The concentration at 2 meters returned to pre-disposal level minutes after the dump occurred, while at the 10-meter depth it stayed below the pre-disposal level.

Figure IV-22  
 Percent transmission  
 Texas City Dump No. 2 near Buoy B,  
 Dredged material from Texas City Channel Turring Basin  
 October 10, 1975

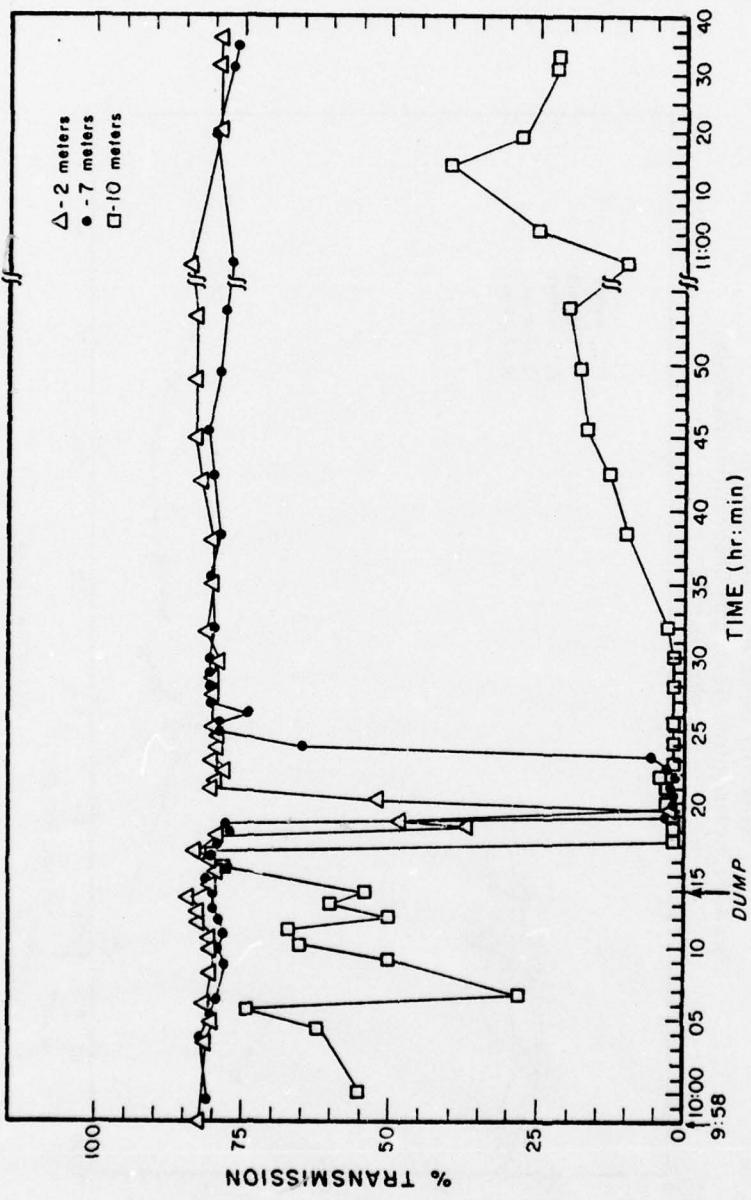
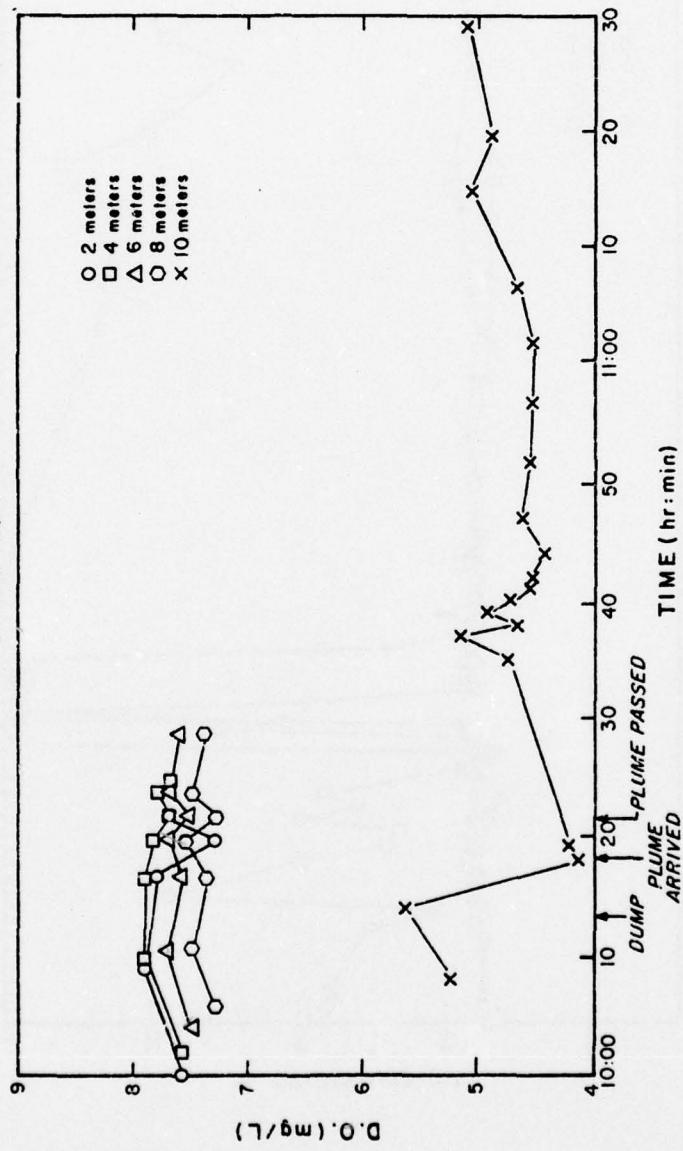


Figure IV-23  
 Dissolved oxygen concentration  
 Texas City Dump No. 2 near Buoy B,  
 Dredged material from Texas City Channel Turning Basin  
 October 10, 1975



Readings were taken twice at the 9-meter depth. At 10:07 the reading was 6.9 mg/l at 9 meters and 5.2 mg/l at 10 meters. At 11:07 it was found to be 5.5 mg/l at 9 meters and 4.6 mg/l at 10 meters. These readings indicate that depletion of oxygen occurred in the bottom two meters of the water column.

Heavy metals. Analytical results for heavy metals are presented in Table IV-60. With the exception of nickel, there were no obvious changes in heavy metal concentrations as a result of disposal. Nickel increases were observed, although only at bottom depths. These levels, however, began to decrease some five minutes after the plume reached the sampling location. In this period, nickel in surface samples also decreased, even though no initial release had been observed. Five minutes after the turbid plume reached the sampling location, concentrations had decreased approximately 9  $\mu\text{g/l}$  from the pre-disposal levels. The concentration of manganese measured at 10:15:50 at 10.5 meters was 838  $\mu\text{g/l}$ , and the concentration of iron at 10:14:15 at 8 meters was 459  $\mu\text{g/l}$ . These values were far outside of the ranges of these metals detected during this dump, and as these samples were not taken in the turbid plume, it is suspected that the high values were due to contamination during collection or handling.

Nitrogen compounds. Table IV-61 presents the results of organic N and ammonium analysis. In Figure IV-24 ammonium concentrations are plotted against time. Release of ammonium in the bottom water was observed, but the concentrations in the overlying water remained below 0.05 mg N/l except for one sample each of surface and mid-depth water. From the figure, it appears that a statistically significant amount (1.86 mg N/l) of ammonium was present in the water at 10:15:50. However, this concentration persisted at the sampling location for less than one

Table IV-60  
Soluble Heavy Metal Concentrations: Texas City Dump No. 2 near Buoy B<sub>1</sub>, Dredged  
Material from Texas City Channel Turning Basin

Time of Collection (hr:min:sec)	Depth (m)	Mn	Cr	Cd	Ni	Pb	Zn	Cu	Fe	Hg	As
9:58:30	1.5	14	< 2	0.8	14.5	1.9	9.7	2.9	< 5	0.002	< 2
9:58:45	8	14	< 2	0.8	14.5	2.4	5.3	2.5	11	0.002	< 2
10:01:45	1.5	30	< 2	0.8	14.5	1.9	2.3	2.5	5	0.006	< 2
10:02:25	10.5	25	< 2	0.8	3.1	2.4	13.1	3.0	18	0.016	< 2
10:14:15	8	< 5	< 2	0.6	12.2	6.8	12.9	4.8	459	0.002	< 2
10:15:50	10.5	838	< 2	0.9	6.8	0.9	22.7	2.6	13	0.002	< 2
10:16:10	8	< 5	< 2	0.6	10.5	1.9	7.2	2.8	40	0.002	< 2
10:16:45	8	14	< 2	0.7	14.5	6.8	15.8	4.6	37	0.006	< 2
10:18:00	1.5	16	< 2	0.8	4.1	0.9	4.2	4.3	17	0.002	< 2
10:18:25	10.5	25	< 2	1.1	4.7	2.4	16.9	6.1	9	0.002	< 2
10:19:10	10.5	14	< 2	1.0	12.9	1.9	8.7	6.0	109	0.016	< 2
10:19:40	8	21	< 2	0.7	16.2	2.7	7.4	9.4	212	0.006	< 2
10:19:55	1.5	< 5	< 2	0.6	13.7	1.9	2.2	2.8	13	0.002	< 2
10:20:10	10.5	14	< 2	0.7	18.6	2.7	8.6	2.9	49	0.002	< 2
10:20:50	1.5	14	< 2	0.9	15.3	2.4	44.8	2.8	20	0.016	< 2
10:21:10	10.5	30	< 2	1.2	15.3	2.4	17.7	7.5	74	0.012	< 2

(Continued)

Table IV-60 (Continued)

Time of Collection (hr:min:sec)	Depth (m)	Mn	Cr	Cd	Ni	Pb	Zn	Cu	Fe	Hg	As
10:21:50	1.5	<5	<2	0.8	12.1	2.7	6.7	3.1	50	0.023	<2
10:22:45	1.5	30	<2	0.9	12.9	2.2	7.7	2.9	123	0.012	<2
10:23:45	8	19	<2	0.8	4.4	2.8	5.0	4.6	18	0.006	<2
10:24:35	10.5	31	<2	1.2	5.6	2.8	17.1	9.4	41	0.006	<2
10:25:00	8	14	<2	0.8	10.5	1.6	2.7	2.6	11	0.016	<2
10:26:35	10.5	<5	<2	1.0	11.3	2.4	10.2	6.8	98	0.016	<2
10:27:55	8	14	<2	0.9	15.3	2.2	4.8	2.5	10	0.016	<2
10:29:45	8	25	<2	0.7	3.3	2.0	6.5	3.5	13	0.016	<2
10:30:50	10.5	21	<2	0.7	17.0	2.7	9.3	8.9	22	0.006	<2
10:31:35	1.5	21	<2	0.8	12.1	2.2	10.3	3.4	5	0.016	<2
10:34:45	8	27	<2	0.7	3.6	0.9	1.5	2.4	<5	0.002	<2
10:35:10	10.5	10	<2	0.8	3.6	1.4	30.7	4.0	12	0.002	<2
10:39:50	10.5	27	<2	1.0	4.1	0.9	3.3	3.5	5	0.002	<2
10:43:10	8	25	<2	0.8	3.3	2.8	29.0	3.1	7	0.002	<2
10:43:30	10.5	21	<2	1.0	4.4	0.5	26.2	4.3	7	0.002	<2
10:48:00	1.5	32	<2	0.8	3.1	0.9	7.6	2.6	<5	0.002	<2
10:48:30	8	25	<2	0.8	5.0	2.4	11.8	3.1	10	0.002	<2
10:49:00	10.5	21	<2	0.8	3.4	0.9	4.8	3.2	<5	0.002	<2

(Continued)

Table IV-60

Time of Collection (hr:min:sec)	Depth (m)	Mn	Cr	Cd	Ni	Pb	Zn	Cu	Fe	Hg	As
10:55:50	10.5	1.0	<2	0.9	4.4	0.9	3.0	2.6	<5	0.002	<2
11:01:10	10.5	1.0	<2	0.8	4.4	0.9	1.8	2.6	<5	0.002	<2
11:07:25	10.5	1.9	<2	0.9	3.6	2.8	7.7	3.2	1.3	0.002	<2
11:13:30	10.5	1.0	<2	0.9	3.6	0.9	3.7	3.2	6	0.016	<2
11:17:30	1.5	2.5	<2	0.9	4.2	2.8	6.3	3.7	7	0.002	<2
11:18:00	8	2.5	<2	1.0	3.6	2.4	12.7	3.7	6	0.002	<2
11:18:15	10.5	2.5	<2	0.8	5.0	2.4	7.0	2.8	<5	0.002	<2
11:32:40	10.5	1.5	<2	0.8	3.3	2.4	12.3	3.8	6	0.002	<2

Table IV-61  
Organic N and Ammonium Concentrations: Texas City  
Dump No. 2 near Buoy B<sub>1</sub>, Dredged Material  
from Texas City Channel Turning Basin  
 (October 10, 1975)

Time of Collection (hr:min:sec)	Depth (m)	Organic N (mg N/l)	Ammonium (mg N/l)
9:58:30	1.5	0.55	< 0.05
9:58:45	8	0.11	< 0.05
9:59:00	10.5	< 0.05	0.11
10:01:45	1.5	0.59	< 0.05
10:02:00	8	0.07	< 0.05
10:06:45	1.5	-	< 0.05
10:14:00 - Dump occurred.			
10:14:00	1.5	-	< 0.05
10:14:15	8	-	< 0.05
10:14:25	10.5	-	< 0.05
10:15:50	10.5	-	1.86
10:16:10	8	-	< 0.05
10:16:15	1.5	-	< 0.05
10:16:30	10.5	-	0.65
10:16:45	8	-	< 0.05
10:17:25	10.5	-	0.73
10:18:00 - Turbid surface plume arrived at sampling location.			
10:18:00	1.5	0.31	< 0.05
10:18:25	10.5	0.55	0.27
10:19:00	1.5	-	< 0.05
10:19:10	10.5	1.01	0.77
10:19:40	8	0.11	< 0.05
10:19:55	1.5	0.11	< 0.05
10:20:10	10.5	-	0.81

(Continued)

Table IV-61 (Continued)

Time of Collection (hr:min:sec)	Depth (m)	Organic N (mg N/l)	Ammonium (mg N/l)
10:20:30	8	-	0.07
10:20:50	1.5	<0.05	0.05
		10:21:00 - Turbid surface plume passed sampling location.	
10:21:10	10.5	-	0.57
10:21:50	1.5	-	<0.05
10:22:05	10.5	-	0.18
10:22:45	1.5	-	<0.05
10:23:15	10.5	-	0.31
10:23:45	8	0.11	<0.05
10:24:20	1.5	-	<0.05
10:24:35	10.5	0.67	0.49
10:25:00	8	-	<0.05
10:25:20	1.5	-	<0.05
10:26:10	1.5	-	0.13
10:26:25	8	-	<0.05
10:26:35	10.5	-	0.75
10:27:40	1.5	-	<0.05
10:27:55	8	-	<0.05
10:28:10	10.5	-	0.64
10:29:45	8	-	<0.05
10:30:10	10.5	-	0.44
10:30:50	10.5	<0.05	0.51
10:31:35	1.5	<0.05	<0.05
10:31:55	8	-	<0.05
10:32:15	10.5	-	0.52
10:34:45	8	-	<0.05
10:36:49	10.5	-	0.33

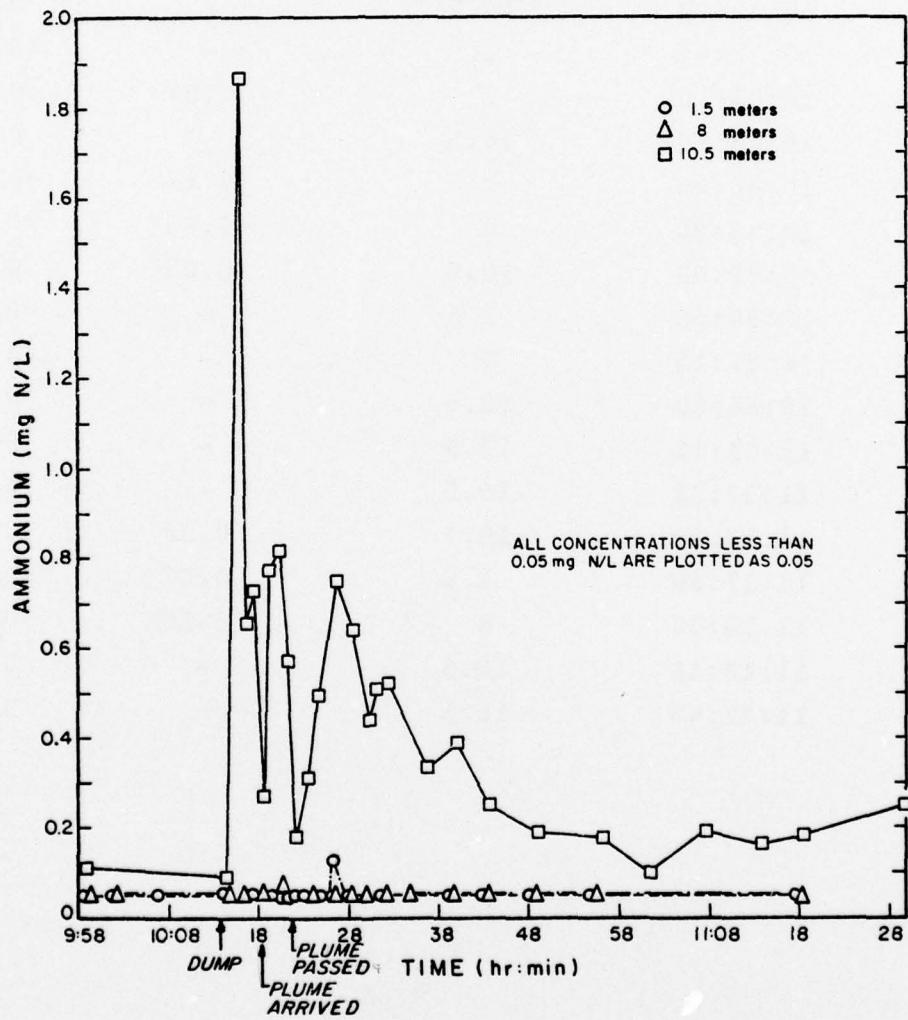
(Continued)

Table IV-61 (Concluded)

Time of Collection (hr:min:sec)	Depth (m)	Organic N (mg N/l)	Ammonium (mg N/l)
10:39:15	1.5	-	<0.05
10:39:30	8	-	<0.05
10:39:50	10.5	-	0.39
10:42:45	1.5	-	<0.05
10:43:10	8	0.07	<0.05
10:43:30	10.5	-	0.25
10:48:00	1.5	0.87	<0.05
10:48:30	8	<0.05	<0.05
10:49:00	10.5	<0.05	0.19
10:54:50	1.5	-	<0.05
10:55:15	8	-	<0.05
10:55:50	10.5	-	0.18
11:01:10	10.5	-	0.10
11:07:25	10.5	-	0.19
11:13:30	10.5	0.08	0.16
11:17:30	1.5	0.07	<0.05
11:18:00	8	0.19	<0.05
11:18:15	10.5	-	0.18
11:32:40	10.5	-	0.25

Dash (-) indicates data not available.

Figure IV-24  
 Ammonium concentrations  
 Texas City Dump No. 2 near Buoy B,  
 October 10, 1975



minute. Organic N was apparently released as a result of the disposal operation in the bottom waters, but it returned to ambient levels 13 minutes after the turbid surface plume arrived at the sampling location. In the surface and mid-depth water, no discernible pattern could be observed.

Phosphorus compounds. Concentrations of soluble ortho P are presented in Table IV-62. Ambient concentrations appear to be 7 to 10 times greater during this disposal operation than they had been during Galveston Dump No. 2 near Buoy B in August. They were also generally higher than concentrations found during the previous day's sampling (Texas City Dump No. 1). There appears to have been a reduction in the concentration of soluble ortho P in the surface water with the passage of the turbid surface plume. Concentrations appear to have gradually dropped from ambient levels (0.07 mg P/l to 0.11 mg P/l) to 0.044 mg P/l about four minutes after the arrival of the turbid surface plume. They increased about 1.8-fold 26 minutes later but dropped to 0.049 mg P/l in another 30 minutes.

Prior to the drop in percent light transmission at mid-depth (Figure IV-22), soluble ortho P concentrations varied between 0.019 and 0.108 mg P/l. The concentration at mid-depth was greatest (0.141 mg P/l) in the sample collected during the lowest percent light transmission. It dropped 50 percent when the percent light transmission increased 4 minutes after the initial drop. After the percent light transmission returned to and remained at ambient levels (~10:25:00) soluble ortho P fluctuated between 0.021 and 0.105 mg P/l without an apparent pattern.

Before the reduction in percent light transmission in bottom waters, soluble ortho P concentrations varied from 0.067 to 0.097 mg P/l. Coincident with the drop in percent light transmission, soluble ortho P concentrations increased to 0.559 mg P/l. For the duration of the sampling period,

Table IV-62

Soluble Orthophosphate Concentrations: Texas City Dump  
No. 2 near Buoy B<sub>1</sub>, Dredged Material from Texas  
City Channel Turning Basin  
(October 10, 1975)

Time of Collection (hr:min:sec)	Depth (m)	Soluble Orthophosphate (mg P/l)
9:58:30	1.5	0.070
9:58:45	8	-
9:59:00	10.5	0.072
10:01:45	1.5	0.101
10:02:00	8	0.108
10:02:25	10.5	0.097
10:14:00 - Dump occurred.		
10:14:15	8	0.084
10:14:25	10.5	0.067
10:15:50	10.5	0.559
10:16:10	8	0.019
10:16:45	8	0.053
10:18:00 - Turbid surface plume arrived at sampling location.		
10:18:00	1	0.096
10:18:25	10.5	0.176
10:19:10	10.5	0.084
10:19:40	8	0.141
10:19:55	1	0.061
10:20:10	10.5	0.350
10:20:50	5	0.062
10:21:00 - Turbid surface plume passed sampling location.		
10:21:10	10.5	0.054
10:21:50	1.5	0.054

(Continued)

Table IV-62 (Concluded)

Time of Collection (hr:min:sec)	Depth (m)	Soluble Orthophosphate (mg P/l)
10:22:45	1.5	0.044
10:23:45	8	0.076
10:24:35	10.5	0.167
10:25:00	8	0.049
10:26:35	10.5	0.086
10:27:55	8	0.049
10:29:45	8	0.077
10:30:50	10.5	0.139
10:31:35	1.5	0.045
10:34:45	8	0.058
10:35:10	10.5	0.070
10:39:50	10.5	0.069
10:43:10	8	0.105
10:43:30	10.5	0.136
10:48:00	1.5	0.079
10:48:30	8	0.021
10:49:00	10.5	0.041
10:55:50	10.5	0.070
11:01:10	10.5	0.076
11:07:25	10.5	0.072
11:13:30	10.5	0.064
11:17:30	1.5	0.049
11:18:00	8	0.042
11:18:15	10.5	0.026
11:32:40	10.5	0.033

Soluble ortho P concentrations based on a single analysis of one sample.

Dash (-) indicates no data available.

the concentrations fluctuated between 0.041 and 0.350 mg P/l. There was no apparent correlation between these levels and percent light transmission. Since the pre-disposal concentrations (Table IV-26) fall within this range, the effect of the dredged material disposal on the soluble ortho P concentrations is not clear. The final three samples, which were collected about 45 minutes after the disposal, showed about the same concentration as had been found at the outset.

The direction and degree of change in soluble ortho P concentration during the disposal operations appeared to be unrelated to either the disposal site or the source of the dredged material. It did appear, however, that the more highly contaminated TCCTB sediments released less soluble ortho P, and in some cases even removed it. This may have been related in some way to the higher ambient soluble ortho P levels present before disposal. The concentrations of soluble ortho P during the Texas City disposals appeared to be even less related to percent light transmission than it was during the seven GBEC disposals.

Organic carbon, oil and grease. Seven composite samples for soluble TOC and oil and grease analyses were made from subsamples collected before, during and after the passage of the surface turbid plume. One composite sample was made from subsamples collected before the plume arrived. Four composite samples were made from subsamples collected during the plume and two composite samples were made from subsamples collected after the plume passed. Each composite sample was centrifuged at 9000 rpm for 10 minutes to remove particulate matter. For this set of samples no filtration through 0.45- $\mu$  pore size filters was made in order to avoid the possible loss of oil and grease due to adherence to the filter. It is assumed that the TOC and oil and grease in

the centrifuged samples represent the soluble fraction of these two parameters.

Results of pre-, during and post-plume concentrations of soluble TOC are presented in Table IV-63. The table shows that concentration of TOC in the sample composited pre-plume was 21.8 mg/l. Concentration of TOC in the four during-plume composite samples ranged from 15.2 to 27.2 mg/l with an average of 20.7. The two post-plume composite samples contained 26.1 and 26.4 mg/l TOC, respectively. Table IV-63 also presents data on oil and grease. The data show fluctuation of the oil and grease content throughout the passage of the surface turbid plume. The oil and grease content before the plume arrived was 5.9 mg/l. In the four post-plume samples oil and grease ranged from 4.6 to 8.6 mg/l with an average of 6.9 mg/l.

Table IV-63  
Carbon and Oil and Grease in the Water Column  
Texas City Dump No. 2\* near Buoy B  
(October 10, 1975)

Composite Sample**		Time	Soluble TOC	Oil and Grease (mg/l)
Turbid Surface Plume				
Pre-		10:06 to 10:16	21.8	5.9
During	1	10:16 to 10:17	20.8	7.1
	2	10:18 to 10:22	19.7	4.6
	3	10:24 to 10:26	15.2	8.6
	4	10:27 to 10:31	27.2	6.1
Post-	1	10:36 to 10:39	26.1	7.5
	2	10:42 to 10:55	26.4	5.7

\*Dredged material from Texas City Turning Basin.

\*\*Two liters were composited from subsamples collected during the time cited. Each composite sample was centrifuged for 10 minutes at 9000 rpm to remove particulate matter.

The two post-plume samples contained 7.5 and 5.7 mg/l, respectively, with an average of 6.6 mg/l

Statistical analysis of variance was run on the Texas City TOC and oil and grease data. The results indicated no significant difference at a 95 percent confidence level between concentrations of these two parameters, before, during and after passage of the surface turbid plume.

#### Characteristics of Dredging Site

##### Water Column during Dredging

Normally, considerable turbidity is found at the dredging site for hydraulic dredging operations. This arises from the stirring of the sediments by the dredge suction drag arms and by the dredge's propellers. In an effort to determine whether potentially significant release of chemical contaminants was occurring at the dredging site in the GBEC, a monitoring operation was conducted immediately behind the hopper dredge McFarland on August 28, 1975, near GBEC Buoy 5.

Optical properties. The percent transmission data obtained immediately behind the dredge near Buoy 5 is presented in Table IV-64. Examination of this table shows that there is a significant gradient of percent transmission vs. depth with the most turbid water near the bottom.

Temperature, dissolved oxygen, salinity and pH. Dissolved oxygen decreased with increased depth; the inverse was true for salinity. Neither temperature nor pH varied with depth (Table IV-65).

Heavy metals. The concentrations of heavy metals at the dredging site as shown in Table IV-66 were generally lower than those found in the water column during disposal. The only possible exception was mercury

Table IV-64  
Percent Transmission Data: Dredging Site Water  
Column near Galveston Bay Entrance  
Channel Buoy 5  
(August 28, 1975)

Depth (m)	Percent Transmission
2	62
4	43
6	3
8	~1
10	~1

Table IV-65  
Hydrolab Data from Plume Resulting from  
Dredging Operations at Buoy 5  
(August 28, 1975)

Depth (m)	Temp	D.O. (mg/l)	Salinity (°/oo)	pH
1	28.5	7.9	24.0	8.5
3	28.5	7.5	24.0	8.5
5	28.5	7.4	24.8	8.5
7	28.5	7.5	24.8	8.5
12	28.5	7.2	26.2	8.5

Table IV-66  
Heavy Metal Concentrations in Turbid Plume at Dredging Site  
Galveston Bay Entrance Channel Buoy 5\*  
(August 28, 1975)  
(µg/l)

Time of Collection (hr:min:sec)	Depth (m)	Mn		Cr		Cd		Ni		Pb		Zn		Cu		Fe		Hg		As
		SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT			
15:38:30	1	8	8	<2	<2	<0.5	<0.5	3.8	3.8	1.9	2.4	1.6	3.7	4.5	10.7	<5	18.1	0.046	0.105 <2	
15:42:00	1	15	15	<2	<2	<0.5	<0.5	2.8	3.8	3.3	4.3	1.1	3.2	4.0	18.1	<5	12.9	0.042	0.120 <2	
15:44:00	9	15	30	<2	<2	<0.5	<0.5	3.4	8.4	3.3	8.6	1.5	4.8	5.2	7.8	15	11.0	0.036	0.100 <2	
15:48:00	1	15	15	<2	<2	<0.5	<0.5	4.7	4.7	3.3	4.8	1.5	2.9	4.0	5.5	<5	5.6	0.046	0.105 <2	
15:49:00	9	<5	23	<2	<2	<0.5	<0.5	4.1	5.3	2.9	2.9	1.3	1.6	4.8	5.5	<5	25.1	0.042	0.080 <2	
15:51:00	22	<5	15	<2	<2	<0.5	<0.5	4.4	8.4	3.3	8.6	1.0	5.3	4.1	9.3	7	11.0	0.033	0.090 <2	

\*Samples taken in turbid plume created by dredge during dredging.

levels which ranged from 0.033 to 0.046 µg/l. These values were slightly higher than those seen in the past. Other metals showed concentrations in a range similar to background levels, thus indicating no noticeable effect as a result of dredging activity.

Nitrogen compounds. The results for nitrogen compounds are presented in Table IV-67. Ammonium concentrations in almost all water samples analyzed were found to be below 0.05 mg N/l (detection limit). Organic N concentrations showed almost the same pattern as that observed at the disposal site with higher concentrations in the bottom water. An elevated nitrate concentration was observed in the mid-depth water, but this concentration persisted for less than 5 minutes.

Table IV-67  
Organic Nitrogen, Ammonium and Nitrate Concentrations  
in Turbid Plume at Dredging Site, Galveston  
Bay Entrance Channel Buoy 5  
(August 28, 1975)

Time of Collection (hr:min:sec)	Depth (m)	Organic N (mg N/l)	Ammonium (mg N/l)	Nitrate (mg N/l)
15:38:30	1	0.35	<0.05	<0.04
15:42:00	1	0.27	<0.05	0.05
15:44:00	9	0.27	0.05	0.13
15:48:00	1	0.43	<0.05	0.05
15:49:00	9	0.35	<0.05	<0.04
15:51:00	22	0.67	<0.05	<0.04

Phosphorus compounds. Table IV-68 presents soluble orthophosphate concentrations. Although the highest concentration of soluble orthophosphate was only 0.022 mg P/l, it was approximately twice that of the normal GBEC levels.

Table IV-68  
Soluble Orthophosphate Concentrations in Turbid Plume  
at Dredging Site: Galveston Bay  
Entrance Channel Buoy 5  
(August 28, 1975)

Time of Collection (hr:min:sec)	Depth (m)	Soluble Orthophosphate (mg P/l)
15:38	1	0.022
15:42	1	0.013
15:44	9	< 0.01
15:48	1	0.01
15:48	9	0.014
15:51	22 (bottom)	0.017

Concentrations based on one analysis of one sample.

Characteristics of the Disposal Site  
Water Column after Disposal

Two post-disposal surveys were conducted to determine the potential impact of dredged material disposal on the chemical characteristics of the water column at the GBEC Disposal Sites. The first of these occurred September 10, 1975, a lay day for the McFarland. The second was on November 24, about two months after the last disposal of GBEC sediments and about six weeks after disposal of

TCCTB sediments that occurred on October 9 and 10, 1975. In addition, data obtained after each dump are pertinent to post-disposal characteristics, since the passage of the turbid plume frequently was followed until the chemical characteristics of the water column had returned to pre-disposal conditions. Data of this type were presented with the results of the individual disposal operations. This section presents the results of the September 10 and November 24 studies.

Optical properties. The percent transmission data obtained on September 10 and November 24, 1975, are presented in Tables IV-69 and IV-70, respectively. Examination of Table IV-69 shows that the percent transmission ranged from 80 to 90 percent in the surface waters and 5 to 12 percent in the waters immediately adjacent to the sediment. The three sets of data obtained in succession near GBEC Disposal Site Buoy D on September 10 show that there is variability in the optical properties of the water over relatively short periods of time. This type of variability is usually encountered in nearshore natural water systems similar to those at the GBEC Disposal Site. Despite the fluctuations in the percent transmission, the surface water clarity on September 10 was approximately the same as that observed throughout the study.

The November 24 data show a similar pattern to the pre-disposal data in that the water adjacent to the bottom was often more turbid than the surface water. This type of pattern is typically found in natural water systems; it reflects the strong currents of this region that tend to suspend materials from the bottom.

Table IV-69  
Post-Disposal Percent Transmission  
of Water Column near Buoy D  
(September 10, 1975)

Time of Collection (hr:min:sec)	Depth (m)	Percent Trans.	Time of Collection (hr:min:sec)	Depth (m)	Percent Trans.
10:04:30	2	90	10:11:50	10	70
10:04:50	3	85	10:12:00	11	67
10:05:05	4	86	10:12:15	12	63
10:05:20	5	86	10:12:25	13	57
10:05:30	6	86	10:12:40	14	52
10:05:45	7	84	10:12:50	15	30
10:05:55	8	82	10:13:00	16	18
10:06:05	9	81	10:13:15	17	8
10:06:15	10	70	10:14:00	2	84
10:06:30	11	74	10:14:15	3	82
10:06:55	12	70	10:14:20	4	80
10:07:10	13	66	10:14:30	5	81
10:07:25	14	56	10:14:45	6	75
10:07:55	15	41	10:14:55	7	75
10:08:15	16	20	10:15:10	8	72
10:08:40	17	5	10:15:20	9	69
10:10:30	2	88	10:15:30	10	68
10:10:40	3	86	10:15:40	11	67
10:10:50	4	82	10:15:50	12	62
10:10:55	5	83	10:16:00	13	56
10:11:10	6	82	10:16:15	14	44
10:11:20	7	78	10:16:40	15	28-34
10:11:35	8	74	10:16:55	16	22
10:11:40	9	72	10:17:10	17	12

Table IV-70  
Post-Disposal Percent Transmission  
of Water Column  
(November 24, 1975)

Sampling Location	Depth (m)	Percent Trans.	Sampling Location	Depth (m)	Percent Trans.
Buoy B	1	80	Buoy D	13	87
	3	78		15	72
	5	80		17	72
	7	86			
	9	84		G.S. 15(ref)	1
	11	84		3	86
				5	87
Buoy C	1	78		7	84
	3	82		9	70
	5	84		11	58
	7	88		13	59
	9	70		15	55
	11	64			
	13	58	G.S. 27(ref)	1	74
	15	44		3	82
				5	87
Buoy D	1	74		7	87
	3	84		9	88
	7	82		11	66
	9	86		13	54
	11	87		1 m off bottom	56

A comparison of the data taken at the GBEC Disposal Site Buoys B, C and D and Reference Grid Squares 15 and 27 (Table IV-70) shows that the optical properties of the water column were similar at these sites. These data suggest that the disposal operations that took place in late August and September 1975 had no long-lasting effect on turbidity and water clarity at the disposal sites.

Temperature, dissolved oxygen, salinity and pH.

Table IV-71 presents the November 24 data obtained at 10:00 at Buoy B. The temperature profile shows a homogeneous layer, 17.0°C, seven meters deep and a layer of warmer water, 19.5°C, near the bottom. The salinity profile also indicated a relatively homogeneous layer (25.5 ‰) seven meters deep. There was a more saline layer of 27.7 ‰ near the bottom. The D.O. concentration generally decreased with depth, with 11.8 mg/l at the surface, 10.8 mg/l at mid-depth and 10.2 mg/l near the bottom. The pH of both surface and bottom waters was 8.6; the mid-depth waters pH was 8.7.

Table IV- 71  
Post-Disposal Water Column Measurements: Galveston Bay  
Entrance Channel Disposal Site Buoy B  
(November 24, 1975-10:00)

Depth (m)	Temperature (°C)	D.O. (mg/l)	Salinity (‰)	pH
1	17.0	11.8	25.0	8.6
3	17.0	11.0	25.5	8.7
5	17.0	10.8	25.5	8.7
7	17.0	11.0	25.5	8.7
9	19.5	10.2	27.7	8.6

The profile measurements near Buoy C, presented in Table IV-72, were taken at 14:50. There was an increase in temperature with depth, similar to that seen near Buoy B. Unlike that at Buoy B, the water was not homogeneous but showed a definite temperature gradient. The surface waters had a temperature of  $16.5^{\circ}\text{C}$ , and the bottom waters,  $21.0^{\circ}\text{C}$ . There was also a decrease in D.O. with depth. Concentrations in the surface water were 11.2 mg/l and in the bottom water, 7.5 mg/l. The salinity showed an increase with depth. It was 24.0 ‰ at the surface and 31.2 ‰ near the bottom. The pH was 8.8 for the upper nine meters and decreased to 8.6 in the bottom water.

Table IV-72  
Post-Disposal Water Column Measurements: Galveston Bay  
Entrance Channel Disposal Site Buoy C  
(November 24, 1975-14:50)

Depth (m)	Temperature ( $^{\circ}\text{C}$ )	D.O. (mg/l)	Salinity (‰)	pH
1	16.5	11.2	24.0	8.8
3	16.5	10.6	25.0	8.8
5	17.0	10.2	25.5	8.8
7	17.0	10.1	25.5	8.8
9	17.5	9.9	26.2	8.8
11	20.5	7.9	30.5	8.7
13	21.0	7.5	31.2	8.6

The water column measurements presented in Table IV-73 near Buoy D were taken at 11:30. The same pattern of increasing temperature with depth was noted here. The surface waters showed  $16.5^{\circ}\text{C}$  and the bottom waters,

Table IV-73  
Post-Disposal Water Column Measurements: Buoy D  
 (November 24, 1975-11:30)

Depth (m)	Temperature (°C)	D.O. (mg/l)	Salinity (‰)	pH
1	16.5	11.1	25.0	8.8
3	16.0	10.2	25.0	8.8
5	16.5	9.9	25.5	8.8
7	18.5	9.4	26.0	8.7
9	18.5	9.4	28.2	8.7
11	19.5	9.3	29.8	8.7
13	21.0	8.1	30.5	8.7
15	21.5	7.5	35.0	8.6

21.5°C. The D.O. decreased with depth, as had been noted before. The concentration in the surface water was 11.1 mg/l, but it was 9.4 mg/l at mid-depth and 7.5 mg/l in the bottom water. The pH decreased from 8.8 at the surface to 8.6 at the bottom.

The data presented in Table IV-74 were collected in G.S. 15, the reference location, at 13:45. From the surface to 3 meters deep the temperature dropped slightly and then increased with depth; it went from 17.5°C near the surface to 17.0°C at mid-depth and 20.0°C near the bottom. The usual decrease in D.O. concentration was observed. The concentration near the surface was 10.4 mg/l; it decreased to 7.2 mg/l at the bottom. A sharp drop (2.4 mg/l) was noted between the seven- and nine-meter depths. The salinity steadily increased with depth (29 ‰ at the bottom). The pH was a constant 8.8 down to seven meters deep and then dropped to 8.6 at nine meters.

Table IV-74  
Post-Disposal Water Column Measurements:  
Reference Grid Square 15  
(November 24, 1975-13:45)

Depth (m)	Temperature (°C)	D.O. (mg/l)	Salinity (‰)	pH
1	17.5	10.4	24.0	8.8
3	17.0	9.9	25.0	8.8
5	17.0	9.9	26.0	8.8
7	18.0	9.6	27.0	8.8
9	20.0	7.2	29.0	8.6

The data in Table IV-75 present the post-disposal water column measurements made at Reference Grid Square 27 at 12:30. As has been noted for all other locations on this date, the temperature increased with depth. The surface waters were found to be 16.5°C and the bottom waters, 21°C. The D.O. decreased with depth; there was a sharp decline of 2.0 mg/l between the 9-and 11-meter depths. The surface waters were found to have 10.2 mg/l, the mid-depth 9.6 mg/l and the bottom 7.0 mg/l D.O. The salinity increased with depth, rising from 24.0 ‰ in the surface water to 32.0 ‰ at bottom. A pH value of 8.8 was found for the first nine meters. There was a decrease to 8.6 in the bottom waters at 13 meters.

A comparison of the pre- and post-disposal data for the D.O. content of the disposal area showed that the disposal operations had no long-lasting effect on these parameters.

Table IV- 75  
Post-Disposal Water Column Measurements:  
Reference Grid Square 27  
(November 24, 1975-12:30)

Depth (m)	Temperature (°C)	D.O. (mg/l)	Salinity (°/oo)	pH
1	16.5	10.2	24.0	8.8
3	16.5	10.0	25.5	8.8
5	17.0	9.6	26.0	8.8
7	17.5	9.6	27.0	8.8
9	17.5	9.5	27.0	8.8
11	20.5	7.5	31.2	8.7
13	21.0	7.0	32.0	8.6

Heavy metals. The results of soluble heavy metals analyses for September 10 sampling appear in Table IV-76. Comparison of these data with those in Table IV-17 shows these metal concentrations to be within the pre-disposal ranges. Comparison of these levels with those on the preceding day reveals values equal to or below the values observed during Galveston Dump Nos. 6 and 7. However, samples taken at 5 and 11 m did show an unusually high zinc concentration, 29.7 µg/l. Although no values this high were observed the previous day, zinc had been found to fluctuate somewhat. This anomalous value is probably the result of contamination of the samples. Based on this observation, these increases would not necessarily be attributed to the disposal. This was further supported by the absence of similar concentrations during disposal and by the normal values at other depths.

Table IV- 76  
Post-Disposal Soluble Heavy Metal Concentrations:  
Water Column near Buoy D  
(September 10, 1975)  
(µg/l)

Time (hr:min)	Depth (m)	Mn	Cr	Cd	Ni	Pb	Zn	Cu	Fe	Hg	As
10:20	1	32	<2	0.9	3.9	0.9	3.2	3.4	16	0.005	<2
10:21	3	10	<2	0.9	4.1	0.9	12.1	3.8	13	0.005	<2
10:23	5	10	<2	0.9	3.1	0.9	29.7	2.8	16	0.002	<2
10:24	7	10	<2	0.9	4.4	0.9	14.1	2.4	30	0.002	<2
10:25	9	16	<2	0.8	4.4	1.4	4.5	2.6	53	0.002	<2
10:26	11	10	<2	0.7	4.4	1.4	29.7	3.7	40	0.005	<2
10:27	13	27	<2	0.8	4.1	0.9	4.8	2.6	<5	0.002	<2
10:29	14	21	<2	0.8	3.9	0.9	2.4	3.4	295	0.005	<2

The 14-m sample did show an iron concentration of 295  $\mu\text{g/l}$ . The highest iron value the day before was 282  $\mu\text{g/l}$ , with most samples in the range of 20 to 50  $\mu\text{g/l}$ . The bottom sample was the only one to show this increase. A value of this magnitude, however, had frequently been observed in pre-disposal data for disposal site waters.

The results of soluble heavy metal determinations for November 24 are listed in Table IV-77. These data were compared to samples taken in the pre-disposal study period (Table IV-17). In both this set and pre-disposal samples, chromium and arsenic levels were below detection limits. In the pre-disposal samples, Buoy C generally had higher levels than Buoy D. This trend was not observed in the post-disposal survey. All three buoys showed metal concentrations of similar ranges, with the possible exception of manganese. Buoy B showed manganese levels of <5 to 25  $\mu\text{g/l}$ , while Buoys C and D showed a range of 25 to 75  $\mu\text{g/l}$ . Zinc concentrations were found to fluctuate between locations and depths, as they had in the pre-disposal samples. Concentration ranges of zinc did not appear different from the pre-disposal concentrations. This was also the case for the other metals studied. No significant changes were noticed either for the buoys or grid squares. Lead concentrations were somewhat lower in the post-disposal samples, as the November 24 samples showed a lead range of 0.9 to 1.9  $\mu\text{g/l}$  at the five sites shown in Table IV-77.

Nitrogen compounds. The ammonium data for the post-disposal water samples collected from GBEC Disposal Site Buoy D, September 10, 1975, are presented in Table IV-78. The ammonium concentrations for all the samples were found to be the detection limit of <0.05 mg N/l. Water samples

Table IV-77  
 Soluble Heavy Metal Concentrations: Water Column at Galveston Disposal Site  
 (November 24, 1975)  
 ( $\mu\text{g/l}$ )

Sampling Location	Depth (m)	Mn	Cr	Cd	Ni	Pb	Zn	Cu	Fe	Hg	As
Buoy B	1	25	<2	2.1	6.1	1.7	19.8	6.3	5	0.007	<2
	5	13	<2	1.8	3.5	1.5	11.7	3.4	8	0.002	<2
	9	<5	<2	1.5	3.9	1.5	5.9	2.5	<5	0.004	<2
Buoy C	1	6.3	<2	0.9	4.2	1.1	24.2	3.2	13	0.002	<2
	7	25	<2	1.0	3.4	1.4	20.4	3.0	7	0.004	<2
	13	25	<2	0.9	2.4	0.9	12.4	2.2	5	0.002	<2
Buoy D	1	75	<2	1.0	4.9	1.1	27.3	3.7	7	0.002	<2
	8	63	<2	1.1	3.1	1.4	74.7	4.6	10	0.002	<2
	15	25	<2	0.9	4.4	1.1	10.4	4.0	<5	0.002	<2
G.S. 15 (ref)	1	38	<2	1.2	4.2	1.1	20.3	4.3	6	0.002	<2
	8	63	<2	1.0	2.9	1.4	11.4	2.6	6	0.004	<2
	15	38	<2	1.3	3.7	1.5	7.1	1.8	<5	0.004	<2
G.S. 27 (ref)	1	38	<2	1.4	4.6	1.7	15.0	2.8	5	0.002	<2
	8	38	<2	1.4	4.4	1.9	12.6	2.9	<5	0.002	<2
	75	75	<2	1.0	3.1	0.9	13.7	2.6	5	0.002	<2

Table IV-78

Post-Disposal Ammonium Concentrations in Water Column  
near Galveston Bay Entrance Channel  
Disposal Site Buoy D  
(September 10, 1975)

Time (hr:min)	Depth (m)	Ammonium* (mg N/l)
10:20	1	< 0.05
10:21	3	< 0.05
10:23	5	< 0.05
10:24	7	< 0.05
10:25	9	< 0.05
10:26	11	< 0.05
10:27	13	< 0.05
10:29	14	< 0.05

\*Ammonium detection limit for procedures used was  
< 0.05 mg N/l.

collected from different parts of the disposal sites on November 24, 1975, were analyzed for ammonium. The ammonium data, presented in Table IV-79, show the concentrations for all samples analyzed were found to be below the detection limit. From these data it can be concluded that the disposal operations had no long-term effect on the water column.

Phosphorus compounds. The concentrations of soluble ortho P in samples collected on September 10, 1975, are presented in Table IV-80. Comparison with Table IV-51 shows that these concentrations were similar to those found there just prior to Galveston Dump No. 6, falling within the same range (<0.01 to 0.018 mg P/l).

Table IV- 79  
Post-Disposal Ammonium Concentrations in Water Column  
at Galveston Bay Entrance Channel  
Disposal Site  
(November 24, 1975)

Sampling Location	Depth (m)	Ammonium* (mg N/l)
Buoy B	1	< 0.05
	5	< 0.05
	9	< 0.05
Buoy C	1	< 0.05
	13	< 0.05
Buoy D	1	< 0.05
	8	< 0.05
	15	< 0.05
G.S. 15 (ref)	1	< 0.05
	8	< 0.05
	15	< 0.05
G.S. 27 (ref)	8	< 0.05
	15	< 0.05

\*Ammonium detection limit for procedures used was <0.05 mg N/l.

The November 24 soluble ortho P concentrations are presented in Table IV-81. These concentrations in general were from two to three times greater than those seen immediately following the October Texas City sediment disposal operations (Tables IV-59 and 62). The concentrations of soluble ortho P were from two to ten times greater than they had been following Galveston Dump No. 7 near Buoy D. It seems likely that these increases in soluble ortho P are related to factors other than disposal operations since no

Table IV- 80  
Post-Disposal Soluble Orthophosphate Concentrations  
in Galveston Bay Entrance Channel Disposal Site  
near Buoy D  
(September 10, 1975)

Time of Collection (hr:min:sec)	Depth (m)	Soluble Orthophosphate	
		$\bar{X}$	SD
10:20	1	<0.01	~0.001
10:21	3	<0.01	~ 0
10:23	5	<0.01	~ 0
10:24	7	0.013	0.001
10:25	9	0.01	0.001
10:26	11	0.018	0.004
10:27	13	0.016	0.005
10:29	14	0.015	0.004

Mean and standard deviation are based on duplicate analyses of one sample.

residual increases were found near Buoy D, although disposal had occurred there the previous day. Also, the concentrations had increased in areas where no disposal had occurred (e.g., Reference Grid Square 15.)

#### Post-Disposal Studies, Spring 1976

In the spring of 1976, 276,246 cubic yards of sediment were dredged from the GBEC between February 18 and March 3. This material was dumped near Buoy B. On April 21, 1976, a set of water column and sediment samples were collected from near Buoy B and at G.S. 15. The water column data collected at this time can be considered as additional post-disposal data. In this case,

Table IV-81  
Post-Disposal Soluble Orthophosphate Concentrations  
in Galveston Bay Entrance Channel Disposal  
Site Water Column  
 (November 24, 1975)

Sampling Location	Depth (m)	Soluble Orthophosphate (mg P/l)
Buoy B	1	0.141
	5	0.084
	9	0.087
Buoy C	1	0.085
	7	0.108
	13	0.061
Buoy D	1	0.119
	8	0.021
	15	0.101
G.S. 15 (ref)	1	1.01
	5	0.107
	9	0.093
G.S. 27 (ref)	1	0.103
	7	0.711
	13	0.076

Concentrations based on one analysis of one sample.

the data would be post-disposal to the February 21-March 3 dumping operations. Both the April 21, 1976, and November 24, 1975, post-disposal monitoring followed disposal by about one to two months.

Temperature, dissolved oxygen, salinity and pH.  
 Data for water column measurements made at Buoy B and Grid Square 15 in the GBEC Disposal Site are shown in Tables IV-82 and 83. Temperature decreased with depth, from 22.5 to

22.0°C for Buoy B, and 23.0 to 22.0°C for G.S. 15. The D.O. ranged from 6.9 to 4.9 mg/l for Buoy B and 7.8 to 4.5 mg/l for G.S. 15. The salinity increased with depth at both sites. At Buoy B the salinity ranged from 21.5 °/oo at the surface to 34.2 °/oo at the bottom. At G.S. 15 the salinity ranged from 24.0 °/oo at the surface to 34.2 °/oo at the bottom. The pH ranged from 8.8 to 8.6 for Buoy B and 8.9 and 8.6 for G.S. 15. The Secchi depth readings at both sites were 1.0 meters. The overall general characteristics at the two sites were generally the same.

Table IV-82  
Water Column Measurements: Galveston Bay  
Entrance Channel Disposal Site Buoy B  
(April 21, 1976-9:15)

Depth (m)	Temp (°C)	D.O. (mg/l)	Salinity (°/oo)	pH
1	22.5	6.9	21.5	8.8
3	22.5	6.5	23.0	8.8
5	22.5	6.0	29.2	8.8
7	22.5	5.8	30.0	8.7
9	22.0	4.9	34.2	8.6

Table IV-83  
Water Column Measurements: Galveston Bay Entrance  
Channel Disposal Site Grid Square 15  
(April 21, 1976-10:25)

Depth (m)	Temp (°C)	D.O. (mg/l)	Salinity (°/oo)	pH
1	23.0	7.8	24.0	8.9
3	22.5	7.0	26.5	8.8
5	22.5	5.5	29.2	8.8
7	22.0	5.2	30.8	8.8
9	22.0	4.5	34.2	8.6

Heavy metals. The soluble heavy metal concentrations for April 21, 1976, sampling were determined in order to reveal any changes in this system as a result of the disposal of dredged material and other factors. These data, shown in Table IV-84, were compared to pre-disposal data collected from Buoys C and D on August 27, 1975 (Table IV-18).

The soluble concentrations of chromium, cadmium, nickel, lead, zinc, copper and arsenic in the pre-disposal and post-disposal samples were similar. Soluble mercury, which had been in the <0.001 to 0.020 µg/l range prior to disposal, was in the range of 0.025 to 0.030 µg/l in the April 1976 samples. Although slightly higher, the post-disposal levels were nevertheless within the range that had been observed throughout this study ( 0.001 to 0.046 µg/l). Soluble iron was also slightly higher in the post-disposal samples, with concentrations of 17 to 83 µg/l. The pre-disposal range for soluble iron was 5 to 43 µg/l. Soluble manganese ranged between 41 and 114 µg/l in the post-disposal samples; pre-disposal concentrations were typically under 40 µg/l (one pre-disposal soluble manganese concentration as high as 247 µg/l was observed at Buoy C).

These measurable increases of soluble mercury, iron and manganese in the post-disposal samples may have resulted from the disposal of dredged material in the sampling area or more likely arising from input from other sources. These apparent increases are not significant because concentrations found were within the ranges of ambient Galveston Bay waters seen throughout this study.

Nitrogen compounds. The results of the ammonium analyses performed on water samples collected from the Galveston disposal site on April 21, 1976,

Table IV-84  
Post-Disposal Samples: Galveston Bay Entrance Channel Disposal Site  
(April 21, 1976)  
( $\mu\text{g/l}$ )

Sampling Location	Depth (m)	Mn	Cr	Cd	Ni	Pb	Zn	Cu	Fe	Hg	As
Buoy B	1	41	<2	1.1	6	11.1	23.7	4.2	17	0.025	<2
	5	78	<2	1.0	7.5	10.2	22.7	3.9	77	0.025	<2
	9	59	<2	0.5	7.3	11.6	23.4	3.7	67	0.030	<2
	1	59	<2	0.7	7.9	11.1	31.2	3.7	47	0.025	<2
	5	114	<2	0.8	7.9	11.1	32.7	4.0	26	0.025	<2
	9	97	<2	0.7	6.7	11.6	45.4	3.1	83	0.025	<2

are presented in Table IV-85. Ammonium concentrations in the water samples from Buoy B were slightly higher than that from G.S. 15. Concentrations were also higher than the post-disposal samples collected from Buoy B in November, 1975. These apparent differences in concentrations, however, are well within the range of the values normally found in this area and do not exceed concentrations which are critical to aquatic life.

Table IV-85  
Post-Disposal Ammonium Data: Water Samples  
from Galveston Bay Entrance  
Channel Disposal Site  
(April 21, 1976)

Sampling Location	Time	Depth (m)	Ammonium (mg N/l)	
			$\bar{X}$	SD*
Buoy B	9:20	1	0.08	0.01
	9:20	5	<0.05	~0
	9:20	9	0.08	0
G.S. 15 (ref)	11:00	1	<0.05	~0
	11:00	5	<0.05	~0
	11:00	9	0.05	0

\*Standard deviation calculated from duplicate analyses.

Phosphorus compounds. Mean soluble ortho P concentrations found in samples collected at Buoy B and G.S. 15 on April 21, 1976, are presented in Table IV-86. Compared with concentrations found in the same areas in November, 1975 (Table IV-81), the April 1976 concentrations were all lower. In general, the concentrations found at Buoy B following disposal operations in August and October, 1975 (Tables IV-37 and IV-62) were lower than

Table IV-86  
Mean Soluble Ortho P Concentrations:  
Galveston, Texas, Disposal Area  
(April 21, 1976)

Site	Time	Depth (m)	<u>Soluble Ortho P*</u>	
			$\bar{X}$	SD
Buoy B	9:20	1	0.092	0.001
		5	0.042	0
		9	0.034	0.002
G.S. 15 (ref)	11:00	1	0.038	0.002
		5	0.026	0.002
		9	0.032	0

\*Mean ( $\bar{X}$ ) and standard deviation (SD) calculated from duplicate analyses of one sample.

those found in April 1976. Soluble ortho P levels in May and June, 1975 (Table IV-26) had a higher surface concentration but lower mid-depth and bottom concentration than was found in April 1976. There appeared to be no consistent pattern of soluble ortho P concentration with depth at these two stations. At Buoy B, the highest concentrations were found in November, the lowest in August. Although very few samples were taken, this pattern may be related somewhat to the phytoplankton growth cycles. These sample sets indicate the variability in soluble ortho P concentrations in the Galveston Bay disposal area throughout the study period.

Organic carbon, oil and grease. Results for total and soluble organic carbon for April 1976 are presented in Table IV-87. Near Buoy B, the TOC values at the 1-, 5- and 9-m depths ranged from 46.6 to 38.5 mg/l. These

Table IV-87

Total and Soluble Organic Carbon: Water Column Samples  
Collected from Buoy B and G.S. 15  
 (April 21, 1976)

Site	Time	Depth	Total TOC	Soluble TOC
			mg/l	
Buoy B	9:20	1	46.6	9.2
		5	43.4	15.2
		9	38.5	7.3
G.S. 15	11:00	1	27.8	6.6
		5	42.2	7.9
		9	44.9	2.9

data show that 65 to 81 percent of the organic carbon is associated with the particulate matter present in the water column. The variability of TOC with depth is insignificant at the 95 percent confidence level. However, soluble TOC data show significant variability with depth. The highest concentration was detected in the 5-m depth (15.2 mg/l). This may indicate degradation of organic matter as a result of high biological activity at this depth.

In G.S. 15 TOC values at 1-, 5- and 9-m depths ranged from 27.8 to 44.9 mg/l. The percent TOC associated with particulate matter ranged from 81.3 to 93.7. Variability of TOC with depth showed a significant difference at the 95 percent confidence level. The lowest TOC value (27.8 mg/l) was detected in the water column sample collected at 1-m depth. The 5- and 9-m depth samples contained comparable TOC concentrations (42.2 and 44.9 mg/l). Soluble TOC also showed significant variability with depth. The highest concentration (7.9 mg/l) was detected in the 5-m depth.

For Buoy B soluble TOC data at 1-m depth were compared with values previously detected post-plume in Texas City Dump No. 2. The post-disposal TOC was 9.2 mg/l, less than the 26.4 mg/l previously detected in Buoy B, post-plume (Table IV-63).

PART V: CHARACTERISTICS OF DREDGING AND  
DISPOSAL SITE SEDIMENTS

Introduction

This section presents the results of the studies on the physical and chemical characteristics of the dredging and disposal site sediments. The sediment data presented in this report generally represent samples obtained by D. Harper as part of the Texas A&M studies on benthic organisms. No samples were provided for certain areas. Some samples were obtained from A. Bouma of Texas A&M as part of his studies of sediment transport and characteristics.

The discussion of the sediment data presented in this report assumes that the data were representative of the general properties of the sampling site at the time of sampling. However, it is well known that natural water sediments in areas such as that near Galveston Bay Entrance Channel tend to be highly variable in composition at one location and tend to change in composition with time, especially when influenced by storms and passing ships. This means that the interpretation of the significance of the chemical characteristics of the data presented in this report must be done with great caution. It is likely that the characteristics of the sediments changed during the course of the study due to factors other than dredged material disposal in the region. Further, it is probable that numbers of samples taken were insufficient to determine with any degree of reliability changes in the chemical characteristics due to dredged material disposal. No studies of the chemical characteristics of the sediments were conducted at the dredged material disposal site for Texas City dumps

due to funding limitations and the small amount of material dumped at the disposal site.

#### Disposal Area Sample Nomenclature

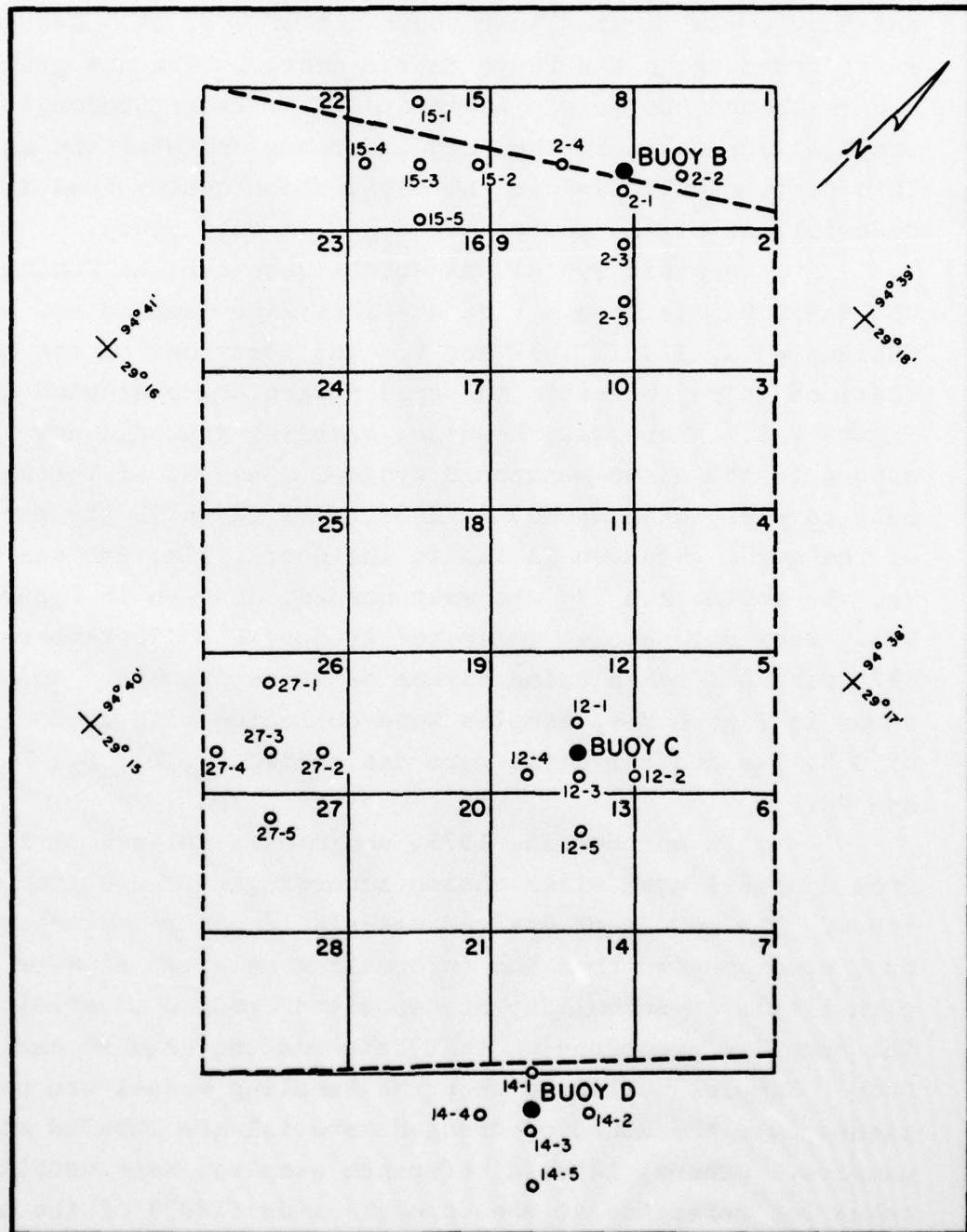
The Galveston Bay Entrance Channel (GBEC) disposal area designated by the U. S. Army Corps of Engineers can be seen in Figure III-1. It was located between the latitudes  $29^{\circ}19'$  and  $29^{\circ}14'$  and longitudes of  $94^{\circ}42'$  and  $94^{\circ}37'$ . It was a rectangle with the dimensions of 3.5 miles by 2.0 miles. The area was divided into a grid with 28 grid squares, referred to by their grid square (G.S.) numbers throughout this report. They were 0.5 miles on a side. Marker buoys were to be placed in specified grids: Buoy B in G.S. 2, Buoy C in G.S. 12, and Buoy D in G.S. 14. After the completion of the study, it was found that the buoys were misplaced and were located in the wrong grid squares. For the purposes of this discussion, it is assumed that the data obtained in the various grid squares where the buoys were to be located is generally representative of the data that would have been obtained from the grid squares where the buoys were actually located. It should be noted that because of the poor navigation system used by those who collected the sediment samples for this part of the study, it is likely that what is labeled a particular pre-disposal grid square represents a sample taken in that general area. It could have easily been derived from an adjacent grid square as well. The error caused by misplacement of the buoys will not change the overall conclusions on the significance of the chemical contaminants present in the dredged sediments on sediment and water quality at the disposal sites.

As shown in Figure V-1, Buoy B was located on a line between G.S. 1 and 8. Buoy C was located in G.S. 12 and Buoy D was located just southeast of G.S. 14. New grids were formed using the buoys as the center. The new grid square around Buoy D was designated G.S. 14a. Sediment samples were taken in the grid locations and near the buoys. This section will explain the designation system used in all descriptions of the sediment samples in this study.

A basic system was established for the naming of the sampling stations. Five stations were sampled and were designated I, II, III, IV and V. The locations of the sample stations in reference to the grid square are presented in Figure V-2. There was, however, sampling that did not adhere to the above-mentioned system. Several of the sediment samples taken on May 6, 1975, were taken in the corners of the grid. Station Ia was in the north; IIa, the east; Va, the south; and IVa the west corner, as seen in Figure V-3. Sediment samples collected at Buoy D on September 10, 1975, were not taken using either of these systems. As shown in Figure V-4, samples were collected both in and out of G.S. 14a and the sites were designated  $D_A$ ,  $D_B$ ,  $D_C$ ,  $D_D$ , and  $D_E$ .

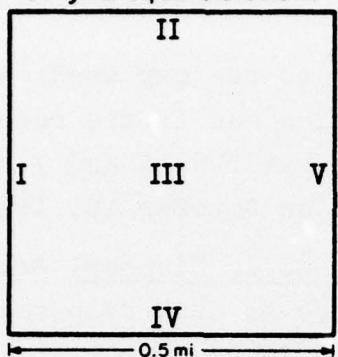
On October 10, 1975, sediment samples were taken from disposal area sites chosen according to the bottom contours. The mounds of dredged material deposited at each buoy were located from the information on a map as were areas with little or no buildup of deposited dredged material. The sampling procedure on that date was the same at each buoy. Samples collected when the sampling vessel was positioned over the mound of dredged material are labeled mound samples. Others, labeled reference samples, were usually taken for reference at the opposite side ( $180^\circ$ ) of the buoy

**Figure V-1**  
**Location of sampling stations**



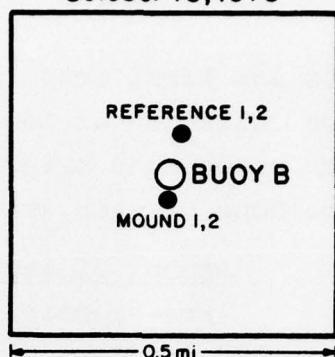
**Figure V-2**

General location  
of grid square stations



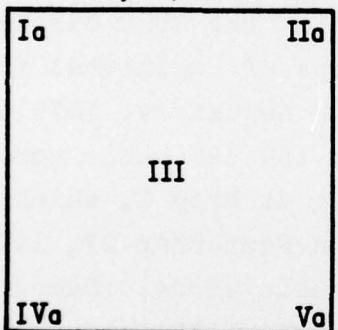
**Figure V-5**

Buoy B  
Location of samples  
October 10, 1975



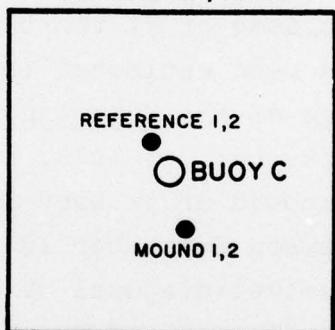
**Figure V-3**

Location of grid square stations  
May 6, 1975

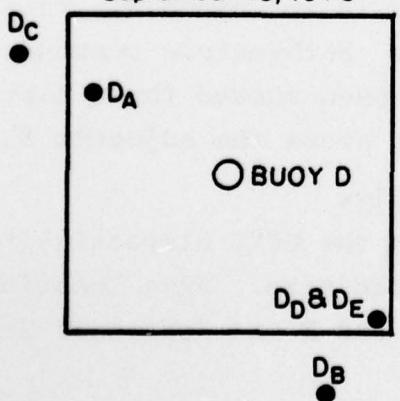


**Figure V-6**

Buoy C  
Location of samples  
October 10, 1975

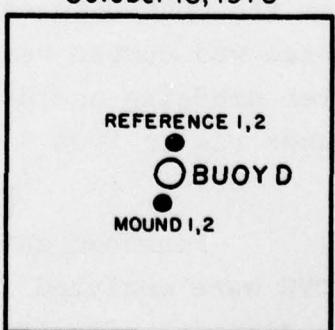


**Figure V-4**  
Buoy D, Grid Square 14a  
Location of samples  
September 10, 1975



**Figure V-7**

Buoy D  
Location of samples  
October 10, 1975



from the first set. According to the map used, samples were collected at locations which had little recent deposition of dredged material. Figures V-5, 6 and 7 show the locations of each station used on October 10, 1975.

Amount of Sediment Dumped in Disposal Area

Pre-disposal bathymetry of GBEC disposal areas is presented in Figure III-2 and discussed in Part III. Dredging and disposal of sediment from the GBEC occurred between August 24, 1975, and September 24, 1975, with disposal occurring near Buoys B, C and D of the GBEC Disposal Site. The total volume of dredged material disposed of at the three buoys in the GBEC disposal area has been estimated (by the Corps of Engineers) from the logs of the McFarland. Between August 24, 1975, and September 24, 1975, a total of 256,396 cubic yards were disposed of at Buoy B. Dumping at Buoy C, which occurred between September 10, 1975, and September 22, 1975, involved disposal of 137,933 cubic yards. Dumping at Buoy D occurred between August 28, 1975, and September 10, 1975, and consisted of 255,618 cubic yards at that site. On October 9-10, 1975, 3000 cubic yards of material dredged from the TCCTB was disposed of at Buoy B<sub>1</sub>. In the spring of 1976, 276,246 cubic yards of sediment were dredged from the GBEC between February 18 and March 3. This material was dumped near Buoy B. Bathymetric contours taken after dredging and disposal ceased showed three distinct mounds rising from 4 to 6 feet above the adjacent flats.<sup>27</sup>

Particle Size

Fourteen samples from the GBEC Disposal Site and the TCCTB were analyzed for particle size. Five locations in the disposal site (Buoys B, C and D and Reference Grid

Squares 15 and 27) were sampled both before and after disposal operations. These samples (Table V-1) showed results comparable to those found by Bouma *et al.*<sup>27</sup> Within the disposal site, there was a trend for the sand content to decrease and clay and silt content to increase with the more seaward samples.

Dredging site sediment composition was also studied. As can be seen in Table V-1, GBEC Buoy 1 sediment was composed almost entirely of sand (97 percent) while Buoy 11 sediment was 89 percent sand and 6 percent clay. As expected, the two TCCTB samples showed a markedly different composition. They were high in clay content, 60 to 68 percent, and low in sand content, 4 to 17 percent. Results of particle-size determination presented in Table V-1 show that there was a difference in pre- and post-disposal sediment particle-size composition. In the five locations subjected to both pre- and post-disposal sampling, the quantity of sand-sized particles increased after disposal. This is probably because when dumping occurs, the finer sediment particles were transported out of the area by the current. From the samples analyzed, the disposal operations did appear to cause a definite change in particle-size composition of the sediments. The effects were mostly confined to the increase in sand-sized particles found following disposal.

#### Cation Exchange Capacity

Selected sediments from the Galveston and Texas City dredging sites and from the GBEC Disposal Site (pre- and post-disposal) were analyzed for cation exchange capacity (CEC). The data for these sediments (Table V-2) show a range of 1.0 to 47.1 meq/100 g for the sediments studied. As expected, CEC values were lower for dredging site sediments

Table V-I  
Particle Size in Sediment Samples Collected in  
Galveston Bay Area, 1975

Sampling Location	Date of Collection	Particle-Size Distribution (Percent)		
		> 0.005 mm	0.005 to 0.02 mm	< 0.005 mm
<b>GBEC Dredging Sites</b>				
Buoy 1	4/17	97	1	1
Buoy 11	4/12	89	3	2
TCC 4	9/20	4	8	20
TCC 5	9/20	17	9	14
<b>GBEC Disposal Sites</b>				
Buoy B (pre)	5/6	81	4	5
(post)	10/10	90	1	3
Buoy C (pre)	7/12	73	3	4
(post)	10/10	91	2	2
Buoy D (pre)	7/22	38	7	10
(post)	10/10	50	8	11
G.S. 15 (pre) (Ref)	7/23	55	4	8
(post)	10/10	64	7	8
G.S. 27 (pre) (ref)	7/24	10	8	20
(post)	10/10	39	8	10
				43

Table V-2  
Cation Exchange Capacity (CEC) of  
Selected Galveston Area Sediments

Sampling Location	Date Collected	CEC (meq/100 g)
<b>Dredging Sites</b>		
GBEC Buoy 7	4/18	1.0
11	4/18	1.0
TCC 4	9/20	26.5
<b>Disposal Site</b>		
GBEC (Pre-disposal)		
Buoy B	5/6	21.2
C	7/12	1.2
D	7/22	25.9
G.S. 15 (Ref)	7/23	28.2
27 (Ref)	7/24	47.1
GBEC (Post-disposal)		
Buoy B	10/10	1.0
B	10/10	1.0
D	10/10	28.2
G.S. 15 (Ref)	10/10	2.4
27 (Ref)	10/10	9.4

than those for disposal site sediments. This was expected, because according to Bouma et al.<sup>27</sup>, the former are predominantly sandy and the latter predominantly silty clay, although both are composed of silt, sand and clay. Bouma et al.<sup>27</sup> further showed that the clay type changed within the system, between varying ratios of illite, kaolinite

and montmorillonite. This may explain the observed variation in disposal site sediment cation exchange capacity, since compared to montmorillonite, illite and kaolinite show a low exchange capacity.

Eh, Sulfide, Oxygen Demand and Percent Dry Weight

Dredging Sites

Sediment samples were collected in the areas that were to be dredged. These samples were from the GBEC at Buoy 1, Outer Bar Channel at Buoy 9, Inner Bar Channel at Buoy 11 and the TCCTB. The sediments were analyzed for Eh, sulfide concentration, oxygen uptake and percent dry weight (Table V-3). (For location of sampling stations see Figure III-1.) The range of the Eh values for the samples tested was from -143 to -380 mv. The samples collected from the TCCTB after dredging exhibited the lowest readings.

The highest sulfide concentration (1259 mg/kg) was found in Texas City 4 sediment. This sample also exhibited the highest uptake of oxygen per gram dry weight and second highest uptake per cubic meter of sediment. The Texas City samples 1, 2 and 6 also exhibited high sulfide concentrations, 917, 932 and 808 mg/kg, respectively. Buoy 1 and Texas City 5 samples had considerably lower sulfide concentrations, 250 and 140 mg/kg, respectively.

The oxygen uptake test was performed on these samples. It was found that Texas City sites 4 and 6 had the highest oxygen demand both per cubic meter,  $6.0 \times 10^2$  and  $6.1 \times 10^2$  g O<sub>2</sub>/1st hr, respectively, and per gram dry weight, 1.21 and 1.17 mg O<sub>2</sub>/1st hr, respectively. Texas City sediments 1, 2 and 5 had similar oxygen demands,

**Table V-3**  
**Galveston Bay Entrance Channel and Texas City Channel Turning Basin**  
**Dredging Site Sediment Eh, Sulfide, Oxygen Demand**  
**and Percent Dry Weight**

Sampling Location	Date Collected (1975)	Eh (mv)	Sulfide		Oxygen Uptake		Percent Dry Weight	
			$\bar{X}$	SD	Per $m^3$	Per gm dry wt	$\bar{X}$	SD
GBEC								
Buoy 1	6/11	-143	250	32	$3.6 \times 10^2$	0.67	40.7	2.7
Buoy 9	4/12	-	-	-	15.0	0.27	41.2	0.9
Buoy 11	4/12	-	-	-	7.8	0.08	60.0	0.1
Texas City 1	3/28	-282	917	82	$5.0 \times 10^2$	0.66	52.6	0.7
Texas City 2	3/28	-264	932	71	$4.8 \times 10^2$	0.64	51.4	2.1
Texas City 4	9/20	-344	1259	5	$6.0 \times 10^2$	1.21	38.5	0.3
Texas City 5	9/20	-380	140	6	$4.5 \times 10^2$	0.76	44.1	0.9
Texas City 6	9/20	-368	808	73	$6.1 \times 10^2$	1.17	40.1	0.1

On this and subsequent tables,  $\bar{X}$  and SD indicate mean and standard deviation, respectively.

Sulfide determined by triplicate analysis; percent dry weight determined by triplicate analysis.

Dash (-) indicates no determination.

$5.0 \times 10^2$ ,  $4.8 \times 10^2$  and  $4.5 \times 10^2$  g  $O_2$ /1st hr per cubic meter, respectively. They had an oxygen uptake of 0.66 mg  $O_2$ / 1st hr, 0.64 mg  $O_2$ /1st hr, and 0.76 mg  $O_2$ /1st hr per gram dry weight, respectively. The samples from Buoys 9 and 11 had an extremely low oxygen demand according to the test results. The oxygen uptake in the first hour was found to be 15 g  $O_2/m^3$  for Buoy 9 and 7.8 g  $O_2/m^3$  for Buoy 11. The uptake in the first hour for Buoy 9 was 0.27 mg  $O_2/g$  dry weight and for Buoy 11 was an even lower 0.08 mg  $O_2/g$  dry weight.

The percent dry weight was determined for all the samples. The Texas City Site 4 samples exhibited the lowest value, 38.5 percent. The highest value, 60.0 percent, was found with the Buoy 11 sample.

#### Disposal Site

Pre-disposal. Sediment was collected in the GBEC Disposal Site before and after disposal operations. The Eh data (Table V-4) of the pre-disposal sediment samples from the disposal area show a large variation throughout the disposal area. The Eh ranged from -112 mv to -440 mv. A plot of the values on a map of the grid squares (Figure V-8) shows that there is no definite pattern. The mean value for the disposal area was found to be -327 mv with a standard deviation of 79 mv, while the samples from a reference area north of the GBEC (a-h) had a mean of -368 mv with a standard deviation of 17 mv. A statistical analysis of the means was performed using a two-sample t-test, and it was determined that the two means were not statistically significantly different based on a 95 percent confidence interval. It should be noted that the variability between samples as expressed by the standard deviation was lower in the samples from the reference area. It was subsequently found in other

Table V-4

Pre-Disposal Sediment Eh, Sulfide, pH, and Percent Dry  
Weight for the Galveston Bay Entrance Channel  
Disposal Site and Reference Area

Sampling Location	Date Collected (1975)	Eh (mv)	Sulfide (mg/kg)		pH	Percent Dry Weight	
			$\bar{X}$	SD		$\bar{X}$	SD
2	4/17	-339	332	14	8.3	57.3	0.8
3	4/18	-348	526	45	8.3	45.7	0.7
4	4/16	-322	140	6	8.1	58.6	0.6
6	4/17	-359	126	6	8.8	57.3	0.4
7	4/16	-112	525	9	8.7	60.9	0.8
8	4/17	-362	176	7	8.5	65.7	0.3
9	4/17	-388	189	26	8.4	58.6	3.5
10	4/18	-371	118	17	8.1	62.4	3.5
11	4/16	-	-	-	-	60.0	3.3
12	5/3	-383	107	7	8.6	50.8	0.9
13	4/17	-326	73	10	8.6	51.1	0
14	4/16	-355	90	11	8.2	65.4	1.3
15 (Ref)	4/17	-339	48	10	8.2	58.4	0.4
16	4/17	-329	135	5	8.2	67.4	0.7
17	4/29	-369	163	11	7.9	48.6	0.6
18	4/16	-348	231	14	8.3	58.4	1.2
19	5/3	-340	128	0	8.4	45.6	1.0
20	4/16	-355	218	37	8.3	46.6	1.0
21	4/17	-440	170	53	-	44.1	1.0
22	4/17	-305	148	18	8.1	54.2	0.2
23	4/17	-382	293	7	8.1	50.7	1.0
24	4/29	-340	341	8	7.8	43.9	4.7
25	4/16	-320	380	54	7.6	39.2	0.5
26	5/3	-359	178	30	8.5	70.3	1.2
27 (Ref)	4/16	-365	448	19	7.9	33.7	0.2

(Continued)

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(Table V-4 Concluded)

Sampling Location	Date Collected (1975)	Eh (mv)	Sulfide (mg/kg)			Percent Dry Weight	
			$\bar{X}$	SD	pH	$\bar{X}$	SD
28	4/16	-309	252	15	7.9	40.2	2.6
a*	5/13	-355	61	6	9.0	60.6	1.2
b	5/12	-363	33	5	8.9	64.1	0.4
c	5/13	-364	73	8	8.1	62.0	1.0
d	5/13	-377	30	0	8.6	59.6	0.5
e	5/13	-350	51	6	8.5	56.3	0.5
f	5/13	-399	61	6	7.8	55.0	3.1
g	5/13	-384	69	9	8.7	56.8	5.2
h	5/13	-352	94	6	8.5	58.0	0.8

Dash (-) indicates data not available.

Sulfide determined by triplicate analyses; percent dry weight determined by duplicate analyses.

\*Samples a-h from sampling locations north of the GBEC.

studies that the characteristics of the sediments from this reference area (sampling locations a-h) were not representative of the disposal area and therefore no further work was done in this area.

Sulfide concentrations found in the samples ranged from 30 to 526 mg/kg. As with the Eh values, there was no pattern in the sulfide concentrations for sediments plotted on a grid square map, as is evident in Figure V-9. The mean sulfide concentration of the disposal area was 217 mg/kg with a standard deviation of 134 mg/kg, and the reference area mean was 59 mg/kg, with a standard deviation of 21 mg/kg. The same statistical analysis was performed

FIGURE V- 8  
 EH OF GALVESTON DISPOSAL SITE SEDIMENTS  
 SPRING 1975

	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

↔ 0.5 MI ↔

ON THIS GRID AND SUBSEQUENT GRID FIGURES:

BLANK GRID INDICATES NO DATA AVAILABLE

SD = STANDARD DEVIATION

LARGE NUMBER IN CENTER OF GRID REPRESENTS MEAN  
 NUMBER IN UPPER LEFT CORNER OF GRID IS GRID NUMBER

FIGURE V-9  
 MEAN SULFIDE CONCENTRATIONS: GALVESTON DISPOSAL SITE SEDIMENTS  
 (MG/KG)  
 SPRING 1975

	2	3	4	5	6	7
1	332 SD=14	526 SD=45	140 SD=6		126 SD=6	525 SD=9
8	9 SD=7	10 SD=26	11 SD=17	12 SD=7	13 SD=10	14 SD=11
15	176 SD=15	189 SD=26	118 SD=17	107 SD=7	73 SD=10	90 SD=11
16	16 SD=10	17 SD=5	18 SD=11	19 SD=14	20 SD=0	21 SD=53
48	135 SD=5	163 SD=11	231 SD=14	128 SD=0	218 SD=37	170 SD=53
22	23 SD=18	24 SD=7	25 SD=8	26 SD=54	27 SD=30	28 SD=19
148 SD=18	293 SD=7	341 SD=8	380 SD=54	178 SD=30	448 SD=19	252 SD=15

SEE FIGURE V-8 FOR EXPLANATION OF TERMS.

← 0.5 MI →

on the sulfide concentrations as on the Eh values. It was found that at a 95 percent confidence interval the disposal sample mean was significantly different from the reference sample mean.

The pH values of pre-disposal sediment samples were between 7.6 and 9.0 as seen in Table V-4. There was no pattern found when the values were plotted on a grid map (Figure V-10). There were no significant differences in the pH values of the disposal area and the reference area. The pH range was 7.6 to 8.8 in the disposal area and 7.8 to 9.0 in the reference area.

Percent dry weight of each sample was determined; values ranged from 33.7 percent to 70.3 percent dry weight. When the dry weight data were plotted on a grid square map (Figure V-11), it was found that those grid squares on the southern corner tended to have a lower percent dry weight sediment.

Post-disposal. After the initial survey was made, a sediment sampling program was carried out at five locations, G.S. 2, G.S. 12, G.S. 14, G.S. 15 and G.S. 27. These are shown in Figure V-1. The last two grid squares were designated as reference areas within the disposal area. The characteristics measured in the baseline survey were also measured here.

As shown in Table V-5, the pre-disposal sediment samples taken in G.S. 2 on May 6, 1975, show the variability in the measured parameters within the grid area. The sulfide concentrations range from 21 to 337 mg/kg, the Eh from -357 mv to -396 mv, and percent dry weight from 40.6 percent to 59.1 percent. The post-disposal sample collected on June 11, 1975, showed an Eh decrease to -414 mv and an increase in percent dry weight to 70.0 percent, but the sulfide concentration was within the range established earlier.

FIGURE V-10  
PH OF GALVESTON DISPOSAL SITE SEDIMENTS  
SPRING 1975

	2	3	4	5	6	7
8	9	10	11	12	13	14
8.5	8.4	8.1		8.6	8.6	8.2
15	16	17	18	19	20	21
8.2	8.2	7.9	8.3	8.4	8.3	
22	23	24	25	26	27	28
8.1	8.1	7.8	7.6	8.5	7.9	7.9

S.F.E. FIGURE V-8 FOR EXPLANATION OF TERMS.

← 0.5 MI →

FIGURE V-11  
MEAN PERCENT DRY WEIGHT:  
GALVESTON DISPOSAL SITE SEDIMENTS  
SPRING 1975

	2	3	4	5	6	7
1	57.3 SD=0.8	45.7 SD=0.7	58.6 SD=0.6		57.3 SD=0.4	60.9 SD=0.8
8	9 SD=0.3	10 SD=3.5	11 SD=3.3	12 SD=0.9	13 SD=0.0	14 SD=1.3
15	16 SD=0.4	17 SD=0.7	18 SD=0.6	19 SD=1.2	20 SD=1.0	21 SD=1.0
22	23 SD=0.2	24 SD=1.0	25 SD=4.7	26 SD=0.5	27 SD=1.2	28 SD=2.6
54.2	50.7 SD=1.0	43.9 SD=4.7	39.2 SD=0.5	70.3 SD=1.2	33.7 SD=0.2	40.2 SD=2.6

← 0.5 MI →

SEE FIGURE V-8 FOR EXPLANATION OF TERMS.

Table V-5  
Galveston Bay Entrance Channel Disposal Site Sediment Eh,  
Sulfide, pH and Percent Dry Weight  
Grid Square 2 and Buoy B

Sampling Location (G.S.No.or Buoy)	Date Collected (1975)	Eh (mv)	Sulfide (mg/kg)		pH	Percent Dry Weight	
			$\bar{X}$	SD		$\bar{X}$	SD
2	4/17	-339	332	14	8.3	57.3	0.8
2-Ia	5/6	-	86	8	-	58.4	7.3
2-IIa	5/6	-383	337	21	8.1	53.1	0.2
2-Va	5/6	-396	103	16	8.4	59.1	1.0
2-IVa	5/6	-357	21	5	8.1	57.5	2.7
2-III	5/6	-	246	17	-	40.6	0.0
2-III	6/11	-414	21	4	7.9	70.0	0.3
2-II	7/14	-384	35	3	8.2	72.4	0.7
2-III	7/14	-351	316	12	7.8	53.8	0.1
2-V	7/14	-373	-	-	8.2	57.8	0.4
Buoy B							
Mound <sub>1</sub>	10/10	-385	207	21	8.7	67.0	0.6
Buoy B							
Mound <sub>2</sub>	10/10	-	59	4	8.7	76.5	0.2
Buoy B							
Ref <sub>1</sub>	10/10	-373	47	4	8.1	67.2	1.0
Buoy B							
Ref <sub>2</sub>	10/10	-338	23	4	9.0	69.2	0.8
Buoy B-I	11/25	-243	29	4	8.5	69.1	0.8
Buoy B-II	11/25	-263	106	10	8.7	70.3	0.8
Buoy B-III	11/25	-352	340	7	8.6	50.0	6.7
Buoy B-IV	11/25	-337	242	24	8.8	56.2	3.1
Buoy B-V	11/25	-365	191	6	8.4	54.8	4.6

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Sulfide determined by triplicate analyses; percent dry weight determined by duplicate analyses.

Dash (-) indicates no data available.

The second set of post-disposal (after May 8, 1975 dump) samples taken on July 14, 1975, was shown to be within the ranges of the pre-disposal samples, except for G.S. 2-II which had a higher percent dry weight, 72.4 percent, and G.S. 2-III which had a lower pH value, 7.8.

Samples were taken in the area on October 10, 1975, after all disposal had ceased. All samples had a higher pH. The Eh values were again within the range of the pre-disposal samples, while the sulfide concentrations were also within the earlier ranges. Three of the four, however, were at the lower limits of the range.

Samples were taken in the vicinity of Buoy B on November 25, 1975; the data are found in Table V-5. Three of the samples had lower Eh readings of -243 mv, -263 mv and -337 mv, which were more positive than the ranges of the pre-disposal samples. The sulfide concentrations were within the range of the pre-disposal samples. All pH readings were higher, while only two of the percent dry weight readings were higher than those for pre-disposal samples.

Table V-6 shows that the four disposal samples taken at G.S. 12 and Buoy C between May 3, 1975, and August 26, 1975, showed a closer range of values than the set at Buoy B. The Eh ranged from -328 to -385 mv, sulfide from 69 to 107 mg/kg, pH from 8.0 to 8.6 and percent dry weight from 46.5 percent to 67.2 percent. The sample set collected on September 10, 1975, deviated somewhat from the range of the pre-disposal samples. The sulfide concentrations of two of the samples, Buoy C-II and C-IV, were below the lower limit of the range, and C-II was higher than the upper limit. However, Buoy C-III, the sample probably most affected by dredged material disposal, had a sulfide concentration similar to those of the pre-disposal samples. The Eh of the samples

Table V-6  
Galveston Bay Entrance Channel Disposal Site Sediment Eh,  
Sulfide, pH, and Percent Dry Weight  
Grid Square 12 and Buoy C

Sampling Location	Date Collected (1975)	Eh (mv)	Sulfide (mg/kg)		pH	Percent Dry Weight	
			$\bar{X}$	SD		$\bar{X}$	SD
G.S. 12-III	5/3	-383	107	7	8.6	50.8	0.9
G.S. 12-I	7/21	-328	93	7	8.0	67.2	0.9
Buoy C-III	8/26	-370	69	6	8.5	57.9	0.1
Buoy C-III	8/26	-385	75	13	8.3	46.5	5.3
Buoy C-II	9/10	-329	3	5	8.1	56.9	0.8
Buoy C-II	9/10	-355	166	9	8.5	55.7	0.4
Buoy C-III	9/10	-340	86	0	8.6	51.2	0.4
Buoy C-IV	9/10	-312	18	9	8.6	53.2	0.9
Buoy C Ref <sub>1</sub>	10/10	-386	117	6	8.1	56.3	1.0
Buoy C Ref <sub>2</sub>	10/10	-354	95	6	8.5	57.4	0.2
Buoy C Mound <sub>1</sub>	10/10	-389	8	5	8.0	78.4	0.3
Buoy D Mound <sub>2</sub>	10/10	+256	10	5	8.6	74.2	1.7
Buoy C-I	12/3	-375	128	6	8.6	53.6	0.6
Buoy C-II	12/3	-384	186	10	8.3	55.0	4.5
Buoy C-III	12/3	-377	83	4	9.1	71.1	3.1
Buoy C-IV	12/3	-361	65	6	8.5	55.4	4.8
Buoy C-V	12/3	-374	131	13	8.4	55.8	8.6

Sulfide determined by triplicate analyses; percent dry weight determined by duplicate analyses.

stayed within the bounds, except for one sample, Buoy C-IV, which was higher. The pH and the percent dry weight readings for each sample were within the pre-disposal range.

The sampling on October 10, 1975, followed the procedure described earlier in the nomenclature section of sampling the dredging disposal mound and an area not as intensely affected by disposal. The reference samples from the areas not affected by disposal fell within the range of the earlier samples in all characteristics measured. The mound samples, however, showed a much lower sulfide concentration, and higher percent dry weight, and in one case, the Eh was positive.

Additional samples were taken in the Buoy C area on December 3, 1975. All the Eh readings were within the range of the pre-disposal sediment samples. Except for Buoy C-III, the sulfide concentrations were also within the range of the pre-disposal samples. The only pH and percent dry weight readings outside of pre-disposal range were also found at Buoy C-III.

Table V-7 shows five pre-disposal samples taken at the G.S. 14a-Buoy D area (two from G.S. 14a and three from Buoy D). The comparison of the samples taken on September 10, 1975, to the pre-disposal samples collected on August 26, 1975, shows that all post-disposal samples had more positive Eh values. Samples D<sub>D</sub> and D<sub>E</sub> taken at the same location (Figure V-4), showed sulfide concentrations lower than the baseline or pre-disposal range. The percent dry weight of the post-disposal samples were found to be lower in all samples. The sample from Buoy D-Mound<sub>2</sub> had a more positive Eh and lower sulfide concentration than the baseline samples. The values for the parameters measured on October 10, 1975, samples were all within the ranges established by the pre-disposal samples.

Table V-7  
Galveston Bay Entrance Channel Disposal Site Sediment Eh,  
Sulfide, pH and Percent Dry Weight  
Grid Square 14a and Buoy D

Buoy D	Date Collected (1975)	Eh (mv)	Sulfide (mg/kg)		pH	Percent Dry Weight	
			$\bar{X}$	SD		$\bar{X}$	SD
14-III	4/16	-355	90	11	8.2	65.4	1.3
14-V	7/22	-334	116	7	7.8	46.7	0.2
D-III	8/26	-469	61	7	7.9	63.4	0.1
D-III	8/26	-378	43	5	8.3	61.7	0.9
D-III	8/26	-523	46	4	7.6	67.1	1.6
D <sub>A</sub>	9/10	-294	43	9	8.2	60.2	0.3
D <sub>B</sub>	9/10	-318	60	7	8.4	55.2	1.2
D <sub>C</sub>	9/10	-345	48	6	7.9	55.8	1.2
D <sub>D</sub>	9/10	-357	6	10	8.0	52.5	5.4
D <sub>E</sub>	9/10	-328	34	14	8.0	56.8	1.0
D <sub>Ref<sub>1</sub></sub>	10/10	-363	51	6	8.1	56.6	0.4
D <sub>Ref<sub>2</sub></sub>	10/10	-411	-	-	8.2	-	-
D <sub>Mound<sub>1</sub></sub>	10/10	-369	58	5	8.2	63.4	0.1
D <sub>Mound<sub>2</sub></sub>	10/10	-242	11	4	8.0	72.0	9.4
D-I	12/5	-265	51	4	8.1	53.2	0.4
D-II	12/5	-373	51	7	8.5	50.8	1.3
D-III	12/5	-374	35	4	8.1	53.2	0.4
D-IV	12/5	-370	70	7	8.7	76.2	0.6
D-V	12/5	-303	67	6	9.1	57.0	0.1

Dash (-) indicates no analysis made.

Sulfide determined by triplicate analyses; percent dry weight determined by duplicate analyses.

Samples taken near the GBEC Disposal Site Buoy D on December 5, 1975, showed Eh readings which fell within the range of the pre-disposal samples. The exception was Buoy D-I sediment, which was more positive. For sulfide content, only D-III sediment fell outside the range of the pre-disposal samples; it was lower. Only two of the pH readings were within the range, while D-II, D-IV and D-V were above it. All the samples were within the pre-disposal range for percent dry weight except for D-IV which was higher.

Grid Squares 15 and 27 were designated as reference areas for monitoring fluctuations in the measured parameters which might be due to natural phenomena. Table V-8 demonstrates the variability of the Eh, sulfide and dry weight data from G.S. 15. The Eh values ranged from -244 mv to -403 mv, the sulfide concentration ranged from 34 mg/kg to 374 mg/kg, and the percent dry weight ranged from 44.5 percent to 77.8 percent. Table V-9 presents the data from the other reference grid, 27. It shows a similar wide range of values for the sulfide concentrations, 49 mg/kg to 448 mg/kg. The Eh and percent dry weight values also fluctuated but not as dramatically as in G.S. 15.

The plot of sulfide concentration relative to Eh value is presented in Figure V-12. The data show that sulfide is present in sediments which have an Eh of -240 mv or more negative, except for one sample with an Eh of -110 mv.

In April, 1976, ten sediment samples were taken at the same location near Buoy B. The boat was anchored during sampling, and an attempt was made to take replicate samples from the same location. A Shipek grab sampler was used. The samples were analyzed for oxidation reduction potential (Eh), sulfide concentrations, percent dry weight and pH. The data are presented in Table V-10 showing that the Eh ranged

Table V-8  
Galveston Bay Entrance Channel Disposal Site Sediment Eh,  
Sulfide, pH, and Percent Dry Weight  
Grid Square 15 Reference Area

Reference Grid Square 15 Station	Date Collected (1975)	Eh (mv)	Sulfide (mg/kg)		pH	Percent Dry Weight	
			$\bar{X}$	SD		$\bar{X}$	SD
III	4/17	-339	48	10	8.2	58.4	0.4
I	7/23	-244	77	6	8.5	53.8	0.1
III	9/10	-369	374	54	8.0	58.5	0.4
III	9/10	-342	115	4	8.3	70.0	0.1
III	9/10	-357	352	12	8.0	45.6	1.4
III	9/10	-251	321	12	8.1	44.5	0.9
III	10/10	-403	155	6	7.8	52.5	0.2
III	10/10	-400	147	5	7.9	61.2	0.8
III	10/10	-395	157	6	8.7	62.8	2.3
III	10/10	-383	338	56	8.4	52.7	0.1
I	12/4	-330	354	8	8.0	44.8	3.1
II	12/4	-369	288	7	8.6	49.4	1.1
III	12/4	-344	34	5	8.6	77.8	0.3
IV	12/4	-365	232	5	8.9	58.6	1.1
V	12/4	-272	227	11	8.8	52.0	0.1

Sulfide determined by triplicate analyses; percent dry weight determined by duplicate analyses.

Table V-9  
Galveston Bay Entrance Channel Disposal Site Sediment  
Eh, Sulfide, pH and Percent Dry Weight  
Grid Square 27 Reference Area

Reference Grid Square 27 Station	Date Collected (1975)	Eh (mv)	Sulfide (mg/kg)		pH	Percent Dry Weight	
			$\bar{X}$	SD		$\bar{X}$	SD
III	4/16	-365	448	19	7.9	33.7	0.2
III	7/24	-333	61	8	8.1	46.5	0.4
I	7/24	-335	298	20	8.0	42.3	0.4
III	10/10	-290	51	6	8.0	55.8	2.4
III	10/10	-341	58	6	8.3	52.2	0.4
I	12/3	-356	79	0	8.9	47.6	1.3
II	12/4	-353	55	0	8.5	50.4	5.7
III	12/4	-358	83	8	8.4	46.9	0.6
IV	12/4	-382	116	5	9.1	58.8	0.3
V	12/4	-335	49	7	8.5	51.2	5.2

Sulfide determined by triplicate analyses; percent dry weight determined by duplicate analyses.

from -38 to -458 mv with a sample mean of -320 mv with a standard deviation of 137. The sulfide concentrations, based on triplicate analysis, ranged from 10 to 49 mg/kg with the sample mean being 27 mg/kg with a standard deviation of 18. The percent dry weight, based on duplicate analysis, ranged from 79.3 percent to 81.1 percent. The sample mean was 80.4 percent with a standard deviation of 0.6. The pH ranged from 7.8 to 9.0. The ten samples were then composited, homogenized and subsamples were taken for analysis. The data from the analysis is presented in Table V-11. The percent

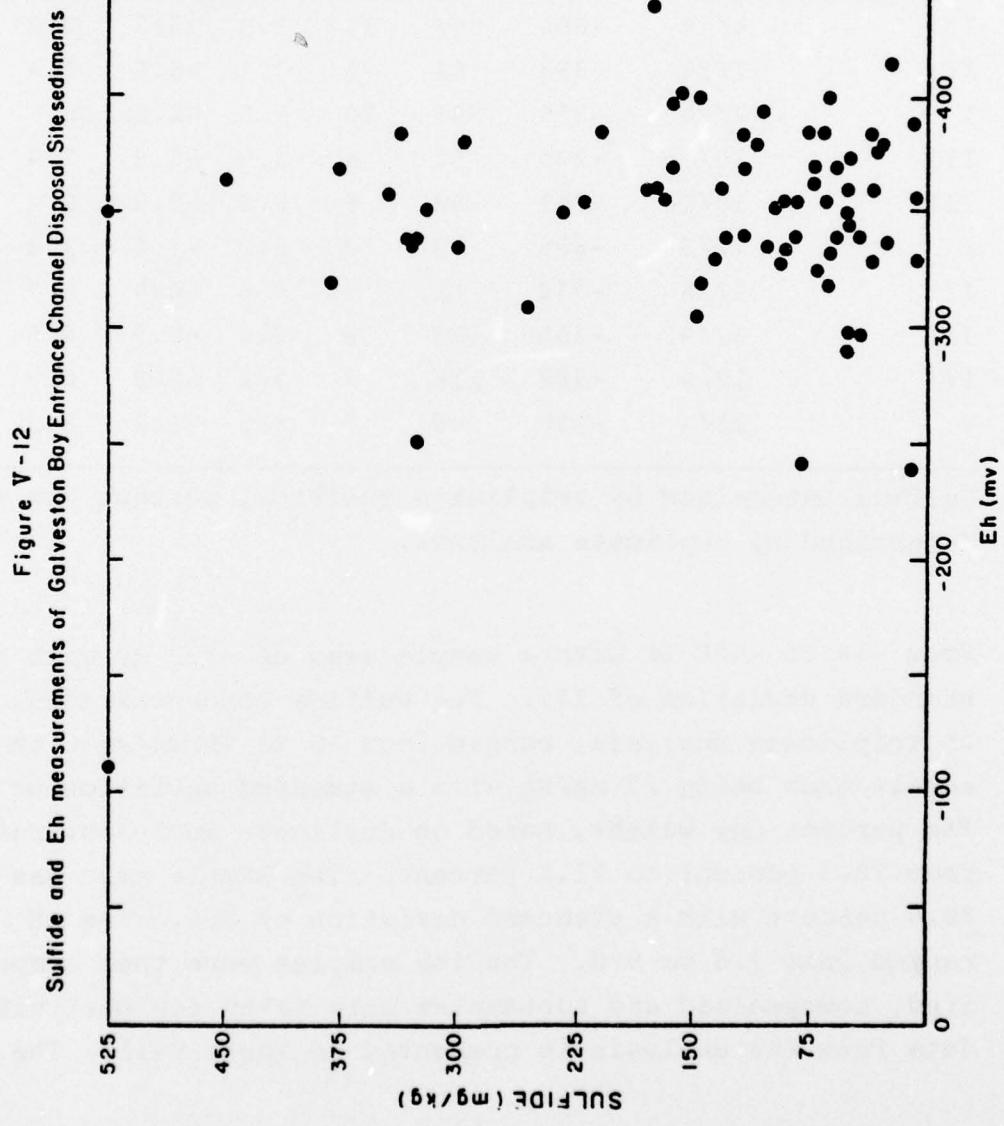


Table V-10  
Sediment Analysis, Buoy B  
Replicate Samples  
(April 1976)

Sample No.	Eh (mv)	pH	S= <u>X</u> (mg/kg)*	Percent ** Dry Weight
1	-410	8.6	12	80.2
2	-432	7.8	46	79.8
3	-312	8.5	39	80.4
4	-386	8.1	11	81.0
5	-38	8.7	49	79.3
6	-301	8.6	34	80.9
7	-433	9.0	11	81.1
8	-288	8.9	10	80.0
9	-458	8.7	10	80.6
10	-142	8.3	42	80.3
$\bar{X}$	-320	-	27	80.4
SD	137	-	18	0.6

\* Triplicate analysis.

\*\*Duplicate analysis.

dry weight mean was 83.6 percent with a 95 percent confidence interval of  $\pm$  0.5. The pH reading ranged from 7.8 to 8.9. These results show good agreement between replicate analysis on a single composited sample and replicate samples taken from one location. Problems were encountered in Eh and sulfide analysis on the composited sample as a result of inadvertently introducing air into this sample.

Eleven sediment samples were collected in April 1976 using a Ponar grab sample while anchored in Grid Square

Table V-11  
Replicate Analysis, Buoy B  
Composite Sediment Sample

Replicate Analysis	pH	Percent Dry Weight
1	7.9	83.9
2	8.6	84.3
3	8.3	84.1
4	8.2	83.9
5	8.0	83.9
6	8.5	83.8
7	7.8	83.1
8	8.9	82.8
9	8.6	83.6
10	8.5	83.0
$\bar{x}$		83.6
SD		0.5

15. The samples were analyzed for the same parameters as the samples from near Buoy B. Table V-12 presents the data from those analyses. The Eh values ranged from -250 mv to -454 mv. The sample mean was -395 mv with a standard deviation of 59. The mean sulfide concentrations ranged from 56 mg/kg to 246 mg/kg. The average of the means was 153 mg/kg with a standard deviation of 63. The percent dry weight means ranged from 45.8 to 54.8 percent. These means averaged to 49.2 percent with 2.6 as the standard deviation. The pH ranged from 8.0 to 9.1.

Table V- 12  
Sediment Analysis, Grid Square 15  
Replicate Samples  
(April 1976)

Sample No.	Eh (mv)	pH	S= (mg/kg)*		Percent ** Dry Weight
			$\bar{X}$	SD	
1	-395	9.1	133	7	49.0
2	-429	8.6	246	7	48.9
3	-420	8.5	129	4	50.3
4	-430	8.0	122	0	45.8
5	-358	8.1	56	6	54.8
6	-250	8.8	234	7	48.1
7	-423	8.7	176	7	49.4
8	-454	8.6	246	7	49.2
9	-447	8.3	129	7	45.8
10	-385	8.8	92	7	48.2
11	-352	8.9	125	7	51.9
$\bar{X}$	-395	-	153	-	49.2
SD	59	-	63	-	2.6

\*Triplicate analysis.

\*\*Duplicate analysis.

These samples were composited, homogenized and subsamples were taken for analysis. Table V-13 presents the data. Eh values ranged from -226 to -378 mv. The mean of the analysis was -320 and had a 95 percent confidence interval of  $\pm$  72. The sulfide concentrations ranged from 0 to 88 mg/kg. The mean was found to be 55 mg/kg with  $\pm$  22 at the 95 percent confidence interval. The percent dry weight was found to range from 48.4 percent to 55 percent. The mean was 52.7 and had a 95 percent confidence interval of  $\pm$  1.1. The pH ranged from 7.8 to 9.0.

Table V-13  
Replicate Analysis, Grid Square 15  
Composite Sediment Sample

Eh (mv)	pH	S= (mg/kg)	Percent Dry Weight
-378	7.8	21	54.3
-368	7.9	0	55.0
-336	8.4	42	52.9
-290	8.6	63	52.6
-226	8.0	73	53.3
	8.1	73	52.7
	9.0	54	52.7
	8.8	64	52.9
	8.7	54	48.4
	8.4	53	52.6
		53	
		42	
		77	
		66	
		88	
X -320	-	55	52.7
SD 63	-	22	1.7

The means of the replicate samples taken at one site and of a composited sample from this site were not significantly different, with a 98 percent confidence interval, for Eh, sulfide, and percent dry weight showing good agreement as seen in Tables V-12 and V-13. A comparison of the results of the replicate sampling of the sediments near Buoy B and G.S. 15 shows similar Eh values were obtained

from the two areas. It was also found that the sulfide concentrations and the percent dry weights of the sediments from the two areas were significantly different.

A comparison of the data presented in Table V-12 with that in V-8 shows that in general the April, 1976, Eh and percent dry weight values were approximately the same as those obtained during 1975 for G.S. 15. The sulfide content for April, 1976, values were lower than the typical values found in 1975. A similar comparison between data presented in Tables V-5 and V-10 for samples taken near Buoy B shows reasonable agreement for both sets of data for Eh, with generally lower sulfide in the April, 1976, samples and lower percent dry weight for the 1975 sampling. These differences may be due to the fact that 276,246 cubic yards of dredged sediment were disposed of near Buoy B in February and March, 1976.

#### Heavy Metals

#### Dredging Sites

The heavy metal content of samples from the GBEC sediments is presented in Table V-14. Iron and manganese were the most abundant metals, ranging from 13.3 to 94.1 g/kg and 1.17 to 1.43 g/kg, respectively. Concentrations varied for the other metals. Cadmium was found to range from <5 to 41 mg/kg. Zinc showed a trend of increasing concentration (12 to 38 to 300 mg/kg) when progressing seaward from GBEC Buoys 11 to 9 to 1, respectively. Other metal concentrations were low with no trends observed.

Pre-disposal sediment samples were taken from the TCCTB on March 28 and September 20, 1975. TCCTB dredging occurred in October. Results of the analyses of these samples are shown in Table V-15. The sediments from the

Table V-14  
Heavy Metal Composition of Sediments from Three Dredging  
Sites in Galveston Bay Entrance Channel,  
April 12, 1975  
 (mg/kg)

Sampling Location (Buoy No.)	Mn*		Cr		Cd		Ni		Pb		Zn		Cu		Fe*	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
1	1.43	0.02	40	25	<5	~0	40	20	15	5	300	0	7.3	2.5	40	1.3
9	1.17	0.13	20	10	41	3	40	10	<10	~0	38	10	2.7	1.2	13.3	2.1
11	1.29	0.05	30	14	38	4	17	16	28	11	12	1	2.5	2.1	94.1	6.9

\*Concentrations in g/kg.

Mean and standard deviation calculated from triplicate analyses.

Table V-15  
Heavy Metal Concentrations, Texas City Channel Turning Basin Sediment  
(mg/kg)

Sampling Location	Date Collected (1975)	Mn		Cr		Cd		Ni		Pb		Zn		Cu		Fe		Hg		As		
		X	SD	X	SD	X	SD	X	SD	X	SD	X	SD	X	SD	X	SD	X	SD			
TCC 1	3/28	840	40	650	20	4.3	0.6	720	20	46	60	235	60	41	2	23,243	260	0.680	0.040	-	-	
TCC 2	3/28	398	20	340	180	4.5	1.3	10	0	62	20	78	10	23	6	17,387	4,740	0.680	0.040	-	-	
TCC 3	3/28	4,680	150	170	90	3.3	0.5	0.5	20	0	88	20	48	10	12	0	33,268	2,280	0.400	0.040	-	-
TCC 4	9/20	556	8	76.5	5.2	<0.5	-	23.5	3.8	<1	-	160.1	3.1	83.3	1.1	26,260	238	0.059	0.12.9	0.1		
TCC 5	9/20	557	21	57.5	4.3	<0.5	-	21.0	1.5	<1	-	113.7	5.9	42.6	0.5	26,000	274	0.037	0.11.8	0.1		
TCC 6	9/20	671	13	90.0	2.6	<0.5	-	24.5	0.9	<1	-	140.9	1.6	60.2	0.9	25,792	477	0.031	0.002	13.1	0.7	

Mean and standard deviations calculated from triplicate analyses.  
Dash (-) indicates data not available.

Turning Basin were higher in copper, chromium, zinc, and lower in lead than GBEC and GBEC Disposal Site sediments (Table V- 14 and Figures V-13-22). Generally, the Texas City sediments would be considered more contaminated than GBEC sediments because of their location in an industrial area. Examination of Table V-15 shows marked changes in the concentrations of chromium, cadmium, lead, zinc and mercury on March 28 and September 20. It appears that the sediments in this region have changed markedly in the content of heavy metals during this period. The cause of this change is unknown at this time.

The metal concentrations in the interstitial water (IW) were determined for some of the sediments studied. These data are listed in Table V-16. Except for iron levels, it was found that the IW concentrations of metals were higher than those in the overlying waters (See Table V-23). The cadmium content varied only slightly from 58.2 to 67.1  $\mu\text{g/l}$ .

#### Disposal Site

Pre-disposal. Pre-disposal metal data for GBEC Disposal Site sediments are found in Figures V-13 through V-22. These samples were obtained in the spring of 1975. The samples showed an iron range from 8 to 35 g/kg and a manganese range from 228 to 723 mg/kg. The chromium levels varied from 19 mg/kg to 108 mg/kg, while cadmium concentrations were below detection limits of 0.5 or 0.3 mg/kg in each grid square sampled. Concentrations of nickel ranged from 9 to 40 mg/kg; copper showed less variation, ranging from 4 to 20 mg/kg. Only G.S. 17 showed a lead level above 50 mg/kg. As was noticed with water samples, the zinc concentrations ranged widely (from 24 to 203 mg/kg). Mercury, lead and arsenic showed generally low concentrations with little variation.

Table V-16  
 Soluble Heavy Metals in Interstitial Water  
From Selected Dredging Site Sediments  
 (μg/l)

Sampling Location	Date Collected (1975)	Mn**	Cr	Cd	Ni	Pb	Zn	Cu	Fe	As
TCC 1	4/12	1.44	< 1.0	58.2	- †	80	115	- †	115	116
TCC 2	4/12	1.92	< 1.0	61.4	-	< 2.0*	120	-	50	116
TCC 3	4/12	44.6	< 1.0	67.1	-	< 2.0*	135	-	26	< 2.0
GBEC Buoy 9	4/12	11.40	< 1.0	59.9	-	85	90	-	< 1.0**	-
GBEC Buoy 11	4/14	27.30	< 1.0	66.9	9.5	18	105	25	196	-

Dash (-) indicates data not available.

\* May be due to instrument malfunction.

\*\* Mn concentrations in mg/l.

† MIBK extracted.

FIGURE V-13  
GALVESTON BAY ENTRANCE CHANNEL DISPOSAL SITE GRID  
PRE-DISPOSAL SEDIMENT MEAN TOTAL IRON CONTENT  
(G/KG DRY WEIGHT)

	2	3	4	5	6	7
	31 SD=1.0	24 SD=3	17 SD=1		35 SD=9	28 SD=7
8	9 SD=2	10 SD=3	11 SD=2	12 SD=0.3	13 SD=.7	14 SD=0.1
13	19 SD=1	18 SD=3	18 SD=2	8 SD=0.3	33 SD=.7	8 SD=0.1
15	16 SD=4	17 SD=1	18 SD=1	19 SD=0.2	20 SD=0.2	21 SD=1
26	17 SD=6	21 SD=4	19 SD=1	8 SD=0.2	8 SD=0.2	31 SD=1
22	23 SD=2	24 SD=5	25 SD=3	26 SD=0.2	27 SD=2	28 SD=0.1
24	20 SD=2	28 SD=3	32 SD=2	9 SD=0.2	35 SD=2	8 SD=0.1

SEE FIGURE V-8 FOR EXPLANATION OF TERMS.

FIGURE V-14  
GALVESTON BAY ENTRANCE CHANNEL DISPOSAL SITE GRID  
PRE-DISPOSAL SEDIMENT MEAN TOTAL MANGANESE CONTENT  
(MG/KG DRY WEIGHT)

	2	3	4	5	6	7
8	372 SD=11	543 SD=47	723 SD=33	482 SD=20	585 SD=91	
228 SD=10	319 SD=31	337 SD=60	673 SD=43	451 SD=60	403 SD=14	441 SD=36
15	16	17	18	19	20	21
442 SD=29	389 SD=6	536 SD=48	570 SD=27	515 SD=25	506 SD=23	619 SD=28
22	23	24	25	26	27	28
416 SD=47	505 SD=9	615 SD=22	573 SD=41	528 SD=48	636 SD=44	515 SD=31

SEE FIGURE V-8 FOR EXPLANATION OF TERMS.

← 0.5 MI →

FIGURE V- 15  
 GALVESTON BAY ENTRANCE CHANNEL DISPOSAL SITE GRID  
 PRE-DISPOSAL SEDIMENT MEAN TOTAL CHROMIUM CONTENT  
 (MG/KG DRY WEIGHT)

	2	3	4	5	6	7
	30	39	22		53	30
8	SD=1	SD=5	SD=1	SD=2	SD=3	
19	32	30	20	61	41	54
SD=2	SD=5	SD=1	SD=1	SD=5	SD=6	
15	16	17	18	19	20	21
27	30	20	32	82	78	40
SD=6	SD=3	SD=1	SD=1	SD=5	SD=8	SD=11
22	23	24	25	26	27	28
SD=4	SD=5	SD=11	SD=6	SD=3	SD=10	SD=6

→ 0.5 MI ←

SEE FIGURE V-8 FOR EXPLANATION OF TERMS.

FIGURE V-16  
 GALVESTON BAY ENTRANCE CHANNEL DISPOSAL SITE GRID  
 PRE-DISPOSAL SEDIMENT MEAN TOTAL CADMIUM CONTENT\*  
 (MG/KG DRY WEIGHT)

	2	3	4	5	6	7
	< 0.5	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3
8	9	10	11	12	13	14
< 0.3	< 0.3	< 0.3	< 0.3	< 0.5	< 0.3	< 0.5
15	16	17	18	19	20	21
< 0.3	< 0.5	< 0.3	< 0.3	< 0.5	< 0.5	< 0.3
22	23	24	25	26	27	28
< 0.3	< 0.5	< 0.3	< 0.3	< 0.5	< 0.3	< 0.5

SEE FIGURE V-8 FOR EXPLANATION OF TERMS.

\* SD= $\sim 0$  FOR ALL GRIDS WHERE DATA ARE GIVEN.

FIGURE V-17  
 GALVESTON BAY ENTRANCE CHANNEL DISPOSAL SITE GRID  
 PRE-DISPOSAL SEDIMENT MEAN TOTAL NICKEL CONTENT  
 (MG/KG DRY WEIGHT)

	2	3	4	5	6	7
1	24 SD=6	21 SD=4	22 SD=5	24 SD=3	30 SD=9	
8	9 SD=2	10 SD=7	11 SD=4	12 SD=.6	13 SD=.6	14 SD=.3
9	15 SD=5	28 SD=7	32 SD=4	23 SD=1	31 SD=.6	22 SD=.3
15	16 SD=1	17 SD=7	18 SD=3	19 SD=6	20 SD=3	21 SD=4
22	23 SD=4	24 SD=12	25 SD=8	26 SD=3	27 SD=7	28 SD=5
						0.5 MI

SEE FIGURE V-8 FOR EXPLANATION OF TERMS.

FIGURE V-18  
 GALVESTON BAY ENTRANCE CHANNEL DISPOSAL SITE GRID  
 PRE-DISPOSAL SEDIMENT MEAN TOTAL COPPER CONTENT  
 (MG/KG DRY WEIGHT)

	2	3	4	5	6	7
	16 SD=1	11 SD=1	6 SD=1		20 SD=0.1	10 SD=1
8	9 SD=8	10 SD=1	11 SD=1	12 SD=2	13 SD=0.4	14 SD=3
4	10 SD=8	9 SD=1	7 SD=0.4	13 SD=2	13 SD=0.4	6 SD=3
15	16 SD=1	17 SD=1	18 SD=0.2	19 SD=2	20 SD=2	21 SD=2
11	11 SD=2	8 SD=1	11 SD=1	17 SD=2	13 SD=2	14 SD=2
22	23 SD=2	24 SD=1	25 SD=1	26 SD=1	27 SD=0.4	28 SD=1
12	13 SD=2	14 SD=1	14 SD=1	17 SD=1	17 SD=0.4	17 SD=1

← 0.5 MI →

SEE FIGURE V-8 FOR EXPLANATION OF TERMS.

FIGURE V-19  
GALVESTON BAY ENTRANCE CHANNEL DISPOSAL SITE GRID  
PRE-DISPOSAL SEDIMENT MEAN TOTAL LEAD CONTENT  
(MG/KG DRY WEIGHT)

	2	3	4	5	6	7
	SD=3	SD=5	SD=8	SD=3	SD=3	SD=3
6	9	10	40	42	12	14
	SD=2	SD=3	SD=3	SD=3	SD=13	SD=2
15	16	17	18	19	20	21
	SD=1	SD=3	SD=11	SD=28	SD=1	SD=0
22	23	24	25	26	27	28
	SD=0.3	SD=1	SD=3	SD=0	SD=1	SD=0
	3	4	28	30	24	25

SEE FIGURE V-8 FOR EXPLANATION OF TERMS.

← 0.5 MI →

**FIGURE V-20**  
**GALVESTON BAY ENTRANCE CHANNEL DISPOSAL SITE GRID**  
**PRE-DISPOSAL SEDIMENT MEAN TOTAL ZINC CONTENT**  
**(MG/KG DRY WEIGHT)**

	2	3	4	5	6	7
1	61 SD=3	42 SD=14	31 SD=3		127 SD=30	41 SD=6
8	9 SD=47	10 SD=10	24 SD=2	38 SD=8	68 SD=3	13 SD=.22
15	16 SD=22	17 SD=1	18 SD=10	19 SD=4	20 SD=9	21 SD=4
150	51 SD=1	49 SD=10	41 SD=4	78 SD=9	86 SD=4	54 SD=8
22	23 SD=8	24 SD=35	25 SD=8	26 SD=1	27 SD=19	28 SD=24

SEE FIGURE V-8 FOR EXPLANATION OF TERMS.

← 0.5 MI →

FIGURE V-21  
 GALVESTON BAY ENTRANCE CHANNEL DISPOSAL SITE GRID  
 PRE-DISPOSAL SEDIMENT MEAN TOTAL MERCURY CONTENT  
 ( $\mu\text{G}/\text{KG}$  DRY WEIGHT)

	2	3	4	5	6	7
	20 SD=5	26 SD=0	18 SD=4		31 SD=2	28 SD=6
8	9 SD=0	10 SD=5		12 SD=4	13 SD=0	14 SD=5
15	17 SD=0	29 SD=5	23 SD=4	29 SD=0	26 SD=0	26 SD=5
15	16 SD=6	17 SD=0	18 SD=2	19 SD=0	20 SD=5	21 SD=0
30	21 SD=0	20 SD=2	17 SD=0	35 SD=5	32 SD=0	38 SD=11
22	23 SD=4	24 SD=12	25 SD=1	26 SD=2	27 SD=1	28 SD=4
23	16 SD=2	23 SD=12	9 SD=1	11 SD=2	7 SD=1	17 SD=4

SEE FIGURE V-8 FOR EXPLANATION OF TERMS.

← 0.5 MI →

FIGURE V- 22  
 GALVESTON BAY ENTRANCE CHANNEL DISPOSAL SITE GRID  
 PRE-DISPOSAL SEDIMENT MEAN TOTAL ARSENIC CONTENT  
 (MG/KG DRY WEIGHT)

	2	3	4	5	6	7
1	10 SD=5	5 SD=5	1 SD=0		14 SD=0.4	8 SD=1
6	9 SD=2	10 SD=1	11 SD=0	12 SD=1	13 SD=0.4	14 SD=1
5	6 SD=2	9 SD=1	3 SD=0	8 SD=1	15 SD=0.4	6 SD=1
15	16 SD=0.4	17 SD=1	18 SD=0	19 SD=1	20 SD=1	21 SD=1
13	14 SD=1	4 SD=1	< 1 SD=0	8 SD=1	7 SD=1	3 SD=1
22	23 SD=1	24 SD=0	25 SD=1	26 SD=1	27 SD=0	28 SD=0.2
9	6 SD=1	5 SD=0	5 SD=1	7 SD=1	2 SD=0	7 SD=0.2

→ 0.5 MI ←

SEE FIGURE V- 8 FOR EXPLANATION OF TERMS.

Post-disposal. Post-disposal sediment samples were taken from the disposal area on September 10, 1975. The data from these samples, presented in Table V-17, can be compared to data for pre-disposal samples from the same sites (Figures V-13 through V-22) to note changes in metal composition as a result of disposal. These samples were collected by Texas A&M staff and sent to UTD for analysis. They did not include any samples from Buoy B or G.S. 2.

The Buoy C samples were compared to the pre-disposal samples collected at G.S. 12 on April 17, 1975. That sample contained 451 mg/kg manganese (Figure V-14) while the highest September concentration was 338 mg/kg. Nickel levels were also lower in the September samples, decreasing from 23 mg/kg (Figure V-17) to a range of 10.8 to 13.5 mg/kg. A similar decrease was noticed for zinc and chromium. The pre-disposal zinc value was 68 mg/kg (Figure V-20) and the post-disposal samples ranged from 55.8 to 63.5 mg/kg. The pre-disposal chromium concentration was 61 mg/kg and the post-disposal range was 21.8 to 42.3 mg/kg. The pre-disposal arsenic concentration was 8 mg/kg (Figure V-22), which was within the range of post-disposal values, 1.0 to 10.9 mg/kg. The same relationship was found for pre- and post-disposal concentrations of cadmium, lead, copper and mercury. Iron concentrations apparently increased as the pre-disposal concentration was 8 g/kg and the post-disposal range was 14.5 to 20.3 g/kg. There was no noticeable difference between the pre-disposal and September 10 sample levels of other metals.

Galveston Bay Entrance Channel Disposal Site Buoy D (G.S. 14a) was not sampled before disposal, but was adjacent to G.S. 14, which had been. If G.S. 14 is considered as representative of G.S. 14a, then the pre-disposal and post-disposal concentrations of these two grids indicate a decrease in manganese from 441 mg/kg to a range of 287 to 314 mg/kg and an increase in iron concentration from 8 g/kg to a range

**Table V-17**  
**Total Heavy Metal Composition of Galveston Bay Entrance Channel Disposal Site**  
**Sediments (Post-Disposal)**  
 (September 10, 1975)  
 (mg/kg)

Sampling Location	Hg		Cr		Cd		Ni		Pb		Zn		Cu		Fe		Mn	
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
Buoy C-I	26.8	21	42.3	2.8	< 0.3	-	10.8	2.2	10.0	0	55.8	4.9	34.6	4.2	19,335	771	0.024	0.008
Buoy C-II	31.3	14	42.3	2.8	< 0.3	-	10.8	2.2	10.0	0	57.6	4.9	21.1	4.3	20,030	42	0.031	0.018
Buoy C-III	33.8	17	37.7	3.7	< 0.3	-	13.5	0.5	10.0	7.1	63.5	1.5	10.7	0	20,340	42	0.016	0
Buoy C-IV	31.8	2	21.8	1.1	< 0.5	-	13.3	1.0	17.7	8.3	59.8	0.2	9.9	0.3	14,469	165	0.044	0.000
Buoy D-I	31.4	8	49.2	14.4	< 0.3	-	6.6	0.5	5.0	0	56.4	3.0	15.0	1.0	29,670	0	0.024	0.008
Buoy D-II	29.5	5	42.9	3.7	< 0.3	-	13.9	2.2	3.0	2.8	65.9	1.1	0.7	0	20,460	382	0.064	0.062
Buoy D-III	31.1	29	53.3	1.8	< 0.3	-	7.7	0	10.0	0	63.2	2.3	3.9	0.4	30,765	2750	0.019	0.002
Buoy D-IV	28.7	13	21.0	2.1	< 0.5	-	12.2	0.6	11.8	0	59.7	3.7	9.7	0.6	14,449	414	0.022	0.006
Buoy D-V	29.3	19	14.3	0	< 0.5	-	12.6	2.1	41.3	8.3	53.6	2.7	7.6	0.3	14,099	248	0.022	0.002
G.S. 15 (Ref) 421	18	22.5	3.2	< 0.5	-	17.8	0	35.4	0	62.3	5.4	11.3	1.0	14,683	524	0.017	0.001	
G.S. 15 (Ref) 391	26	24.0	1.1	< 0.5	-	18.1	1.5	29.5	8.3	69.2	5.4	12.9	0	15,191	248	0.018	0	
G.S. 15 (Ref) 245	12	5.6	0.5	< 0.5	-	10.8	0.5	23.6	16.7	30.4	0.5	3.0	0.3	10,979	303	0.011	0.006	
G.S. 15 (Ref) 432	4	29.9	0	< 0.3	-	9.7	1.6	5.0	0	40.5	1.8	5.7	0	20,790	85	0.064	0.012	

Mean and standard deviation calculated from duplicate analyses.

Dash (-) indicates not determined.

of 14 to 30.8 g/kg. Nickel and arsenic concentrations showed small decreases and concentrations of cadmium, copper, lead, zinc and mercury showed no changes as a result of the disposal operations.

The post-disposal metals concentrations measured in Reference Grid Square 15 in September showed decreases from pre-disposal concentrations of manganese, iron and zinc. The greatest decrease was seen in the concentrations of zinc which was 150 mg/kg pre-disposal and ranged from 30 to 69 mg/kg post-disposal. There were no changes in concentrations of other metals measured.

Duplicate sediment samples were collected near GBEC Disposal Site Buoys B, C and D and Reference Grid Square 27 after disposal on October 10, 1975. In addition, four replicate sediment samples were taken in Reference G.S. 15. These post-disposal samples were taken in order to detect large changes in sediment composition as a result of dredged sediment disposal. The buoy samples were taken from the mounds formed by the disposed material.

The heavy metal composition of sediments collected at Reference G.S. 15-III and G.S. 27-III is presented in Table V- 18. The data show some variation between the four replicates from G.S. 15-III. Manganese and iron concentrations ranged from 295 to 368 mg/kg and 15,071 to 18,918 mg/kg, respectively. Similar variations can be seen for zinc (40.7 to 60.7 mg/kg) and lead (7.5 to 18.2 mg/kg). For five out of ten metals, one replicate sample out of the four showed a value different from the other three, although the outlying sediment was not the same in all cases. For example, nickel ranged from 10.0 to 13.3 mg/kg for three replicates while the fourth showed 5.0 mg/kg. Overall, the metal concentrations were comparable to those detected at Reference G.S. 15 on September 10, 1975. However, the arsenic levels (2.2 to 2.5

Table V-18  
Total Heavy Metal Composition of Galveston Bay Entrance Channel Disposal Site  
Sediments: Reference Grid Squares 15 and 27  
(October 10, 1975)  
(mg/kg)

Sampling Location	Mn		Cr		Cd		Ni		Pb		Zn		Cu		Fe		Hg		As	
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
Ref. G.S.	331	5	13.8	1.1	< 0.5	-	10.0	2.7	18.2	2.0	53.3	3.6	4.9	0.5	15,708	72	0.025	0	2.5	0
15-III (2 replicate samples)	326	3	12.2	0.4	< 0.5	-	11.6	1.1	16.8	0	49.7	0.6	5.4	0.9	15,071	108	0.045	0	2.3	0
368	5	17.4	4.9	< 0.5	-	13.3	0	7.5	0	60.7	1.9	12.2	0.7	18,918	166	0.043	0.004	2.2	0	
295	12	12.5	1.2	< 0.5	-	5.0	0	7.5	0	40.7	1.6	8.0	0	16,004	33	0.045	0	2.2	0	
G.S. 27- III (2 replicate samples)	290	14	17.4	1.6	< 0.5	-	14.1	0	9.0	0	59.6	2.8	9.4	0	19,505	134	0.055	0	2.4	0
	283	20	18.0	1.6	< 0.5	-	13.3	0	12.0	0	57.2	3.7	9.4	0	19,082	133	0.020	0	2.1	0

Mean and standard deviations calculated from duplicate analyses.  
dash (-) indicates not determined.

mg/kg) were considerably lower than those found in September (11.7 to 12.5 mg/kg arsenic for three of the four replicates and 1.3 mg/kg arsenic for the fourth).

There was little variation between the two replicates from Reference G.S. 27-III. Manganese concentrations were 283 and 290 mg/kg, while those for iron were 19,082 and 19,505 mg/kg. The greatest variation in metals concentrations was seen in the mercury levels which were 0.020 and 0.055 mg/kg for the two replicates. For seven metals post-disposal concentrations were lower than pre-disposal concentrations. There was no change in cadmium or arsenic concentrations. Mercury levels were higher post-disposal than the pre-disposal concentration of 0.007 mg/kg (Figure V-21).

Table V-19 shows heavy metals concentrations for duplicate sediment samples collected on October 10, 1975 (post-disposal) on and off of the disposal mounds at Buoys B, C and D. The duplicates were fairly close for most metal concentrations, with iron and manganese levels varying the most. The concentrations observed in October, 1975 (Table V-19) were similar to those observed in September, 1975 (Table V-17) for Buoys C and D. The major exception is chromium. The September ranges for Buoys C and D, respectively, were 21.8 to 42.3 mg/kg and 14.3 to 53.3 mg/kg. The October ranges were 2.9 to 20.5 mg/kg and 14.6 to 19.0 mg/kg, respectively. The metal composition was also examined at different places around the buoy sites. The mound areas were compared to reference areas; at Buoy D there was no major difference in metal concentrations between the two sites except for mercury, which ranged from 0.015 mg/kg to 0.050 mg/kg for the mound and reference samples, respectively. Manganese and iron levels in the Buoy C

Table V-19  
 Heavy Metal Composition of Galveston Bay Entrance Channel  
Disposal Site Sediments: Buoys B, C and D  
 (October 10, 1975)

Sampling Location	<u>Hn</u>		<u>Cr</u>		<u>Cd</u>		<u>Ni</u>		<u>Pb</u>		<u>Zn</u>		<u>Cu</u>		<u>Fe</u>		<u>Hg</u>		<u>As</u>	
	<u>X</u>	<u>SD</u>																		
<u>Buoy B</u>																				
Mound	278	6	8.4	1.2	<0.5	-	5.0	1.2	7.5	0	31.0	2.2	5.6	0.7	14,053	67	0.020	0	2.0	0
Reference	222	14	3.8	0.3	<0.5	-	1.7	0	15.0	2.1	19.4	0	3.8	0	9,071	200	0.023	0.004	2.2	0
Reference	281	17	11.0	1.6	<0.5	-	10.0	0	5.3	3.2	33.9	3.1	7.1	0	15,158	1163	0.020	0	2.2	0
Reference	326	14	11.4	1.5	<0.5	-	9.5	1.9	15.4	2.0	41.6	2.3	1.4	1.6	15,606	72	0.020	0	2.1	0
<u>Buoy C</u>																				
Mound	309	2	3.2	0.4	<0.5	-	3.3	2.3	9.0	0	15.8	0	3.3	0	7,379	332	0.023	0.004	2.2	0
Reference	310	9	2.9	1.1	<0.5	-	5.4	0	8.4	4.0	51.8	46.0	1.4	0.2	7,727	252	0.020	0	2.2	0
Reference	323	0	18.3	1.2	<0.5	-	12.5	1.2	15.8	1.1	59.0	0	10.8	0	18,283	66	0.023	0	2.2	0
Reference	373	35	20.5	1.3	<0.5	-	13.5	2.3	21.0	2.0	66.9	9.8	8.3	1.1	18,743	108	0.020	0	2.2	0
<u>Buoy D</u>																				
Mound	393	6	16.1	0	<0.5	-	12.4	0	15.4	2.0	64.2	28.4	6.3	0	17,723	252	0.020	0	2.2	0
Reference	358	0	14.6	0.7	<0.5	-	10.0	0.4	18.2	2.0	44.2	0	5.8	0	17,442	79	0.015	0.007	2.3	0
Reference	282	0	16.8	0	<0.5	-	10.0	4.7	7.5	4.2	54.1	1.2	10.8	0	19,037	66	0.045	0	2.2	0.1
Reference	358	15	19.0	0.4	<0.5	-	11.6	2.7	16.8	0	90.5	46.9	7.5	0.4	18,794	108	0.050	0.007	2.5	0.3

Mean and standard deviations calculated from duplicate analyses of duplicate samples.

Dash (-) indicates not determined.

reference samples were greater than those found in the mound samples. This was also the case for Buoy B. This trend persisted for chromium, nickel and copper at both Buoys B and C.

Since the mounds were created by the disposal of dredged material, it might be suspected that they exhibit metal concentrations quite different from those at the disposal sites. This does not appear to be the case when the mound and reference site are compared. This may indicate that mixing of the sediments occurs at the site.

Additional sediment samples were collected from the disposal grid area in late November and early December, 1975. Five stations within each grid square were sampled, as discussed in Part III, to assess the variability in metal composition within each grid square. The results of the analyses appear in Table V-20. The data from G.S. 2 contained some variation among grid stations for all metals analyzed. The iron values, which ranged from 12,243 to 18,233 mg/kg had the lowest coefficient of variation ( $V = 14\%$ ) while the chromium concentrations, which ranged from 9.3 to 24.1 had the highest variation ( $V = 36\%$ ). The coefficients of variation for the other metals ranged from 17% to 35%.

The metal concentrations at G.S. 12 (Table V-20) did not vary between stations as much as they had for samples taken earlier in the study. The coefficients of variation for the analyses in this grid were smaller than those for G.S. 2. The highest was for lead ( $V = 36\%$ ) which ranged from 5.3 to 13.7 mg/kg. The lowest was for iron ( $V = 3\%$ ) which ranged from 16,133 mg/kg to 17,304 mg/kg. The coefficients of variation for the other metals ranged from 6% for manganese to 27% for nickel. The samples collected in Grid Square 14 also exhibited some variation in manganese and iron levels. The concentrations found at Station III (except for lead) were well below the ranges found at the other stations; this finding is not understood.

Table V-20  
Total Heavy Metal Composition of Galveston Bay Entrance Channel  
Disposal Site Sediments (Post-Disposal)

Sampling Location G.S.	Date Collected (1975)	Mn		Cr		Cd		Ni		Pb	
		X	SD	X	SD	X	SD	X	SD	X	SD
2-I	11/25	310	22	7.1	12.8	0	<0.5	-	-	4.3	0.3
2-II	11/25	254	4	1.6	9.3	0.8	<0.5	-	-	3.4	0.5
2-III	11/25	390	1	0.3	24.1	1.2	5.0	<0.5	-	6.0	1.1
2-IV	11/25	319	4	1.3	18.0	0.8	4.4	<0.5	-	7.1	0.5
2-V	11/25	380	1	0.3	21.5	0.8	3.7	<0.5	-	6.8	1.6
GROUP MEAN		331	56	16.8	17.1	6.1	35.5	<0.5	-	5.5	1.6
12-I	12/3	351	9	2.6	22.3	1.2	5.4	<0.5	-	8.3	1.6
12-II	12/3	322	28	8.7	22.9	1.2	5.2	<0.5	-	8.1	0.3
12-III	12/3	315	6	1.9	15.7	0.8	5.1	<0.5	-	4.1	0.5
12-IV	12/3	341	16	4.7	23.2	2.5	10.8	<0.5	-	9.4	0.5
12-V	12/3	362	13	3.6	23.5	0.4	1.7	<0.5	-	8.4	1.9
GROUP MEAN		338	20	5.8	21.5	3.3	15.3	<0.5	-	7.7	2.1
14-I	12/5	404	6	1.5	33.6	0.8	2.3	<0.5	-	12.1	0.3
14-II	12/5	344	25	7.3	23.8	0	0	<0.5	-	7.7	1.3
14-III	12/5	321	5	1.6	5.8	0	0	<0.5	-	0.9	0.3
14-IV	12/5	380	20	5.3	20.7	0.8	3.9	<0.5	-	17.2	0.6
14-V	12/5	341	12	3.5	17.6	0.4	2.3	<0.5	-	14.0	1.7
GROUP MEAN		358	33	9.3	20.3	10.1	49.7	<0.5	-	12.1	1.7
15-I(Ref)	12/4	560	22	3.9	20.2	1.6	7.9	<0.5	-	16.0	0
15-II(Ref)	12/4	496	18	3.6	23.8	2.0	8.4	<0.5	-	17.0	0
15-III(Ref)	12/4	224	0	0	3.1	0.4	12.9	<0.5	-	5.6	0
15-IV(Ref)	12/4	341	4	1.2	10.6	0	0	<0.5	-	9.6	1.1
15-V(Ref)	12/4	433	5.3	1.2	18.8	1.2	6.4	<0.5	-	13.2	0.6
GROUP MEAN		411	132.1	32.2	14.4	9.4	65.0	<0.5	-	12.4	4.9
27-I (Ref)	12/4	456	4	0.9	25.2	0.3	1.2	<0.5	-	18.8	1.7
27-II (Ref)	12/4	434	28	6.5	24.1	4.8	19.9	<0.5	-	16.8	1.1
27-III (Ref)	12/4	433	22	5.1	26.6	1.2	4.5	<0.5	-	18.8	0.6
27-IV (Ref)	12/4	377	25	6.6	21.6	2.8	13.0	<0.5	-	14.0	1.7
27-V (Ref)	12/4	418	20	4.8	26.3	2.4	9.1	<0.5	-	20.0	1.1
GROUP MEAN		424	29	6.9	24.8	2.0	8.2	<0.5	-	17.7	2.4

(Continued)

Table V-20 (Concluded)

Sampling Location G.S.	Date Collected (1975)	Zn		Cu		Fe		Hg		As	
		$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
2-I	11/25	38.4	2.5	6.5	5.4	0.3	5.6	14.984	0	0.028	0.1
2-II	11/25	33.8	3.2	9.5	3.8	0	0.1	0.043	0	2.2	4.5
2-III	11/25	61.5	0	9.4	0	0	0.2	0.033	0.002	0	2.3
2-IV	11/25	53.1	3.4	6.4	7.1	0.7	9.9	16.465	0.6	6.1	0.1
2-V	11/25	54.2	0.2	0.4	9.6	0.3	3.1	16.354	0.8	0.019	0
GROUP MEAN		48.2	11.6	24.1	7.1	2.5	35.2	15.656	12.5	0.037	0.004
12-I	12/3	58.6	0.2	0.3	9.9	0	0	17.304	94	0.5	0.002
12-II	12/3	56.4	7.2	12.7	8.7	0.3	3.4	16.818	46.9	2.8	0.004
12-III	12/3	38.7	0	0	6.6	0	0	16.133	250	1.5	0.002
12-IV	12/3	62.0	2.8	4.5	10.8	0.7	6.5	16.907	94	0.6	0.002
12-V	12/3	62.7	0.8	1.3	9.9	0	0	16.995	156	0.9	0.036
GROUP MEAN		55.7	9.8	17.7	9.2	1.6	17.7	16.831	431	2.6	0.004
14-I	12/5	68.6	0.6	0.9	20.7	0.7	3.4	19.139	0	0.028	0
14-II	12/5	60.0	4.2	7.0	9.4	0.3	3.2	17.371	375	2.2	0.002
14-III	12/5	18.9	0.4	2.1	2.8	0	0	9.393	156	1.7	0.002
14-IV	12/5	72.6	4.1	5.6	9.6	0.2	2.1	19.046	30	0.2	0.034
14-V	12/5	67.5	4.5	6.7	10.0	0.6	6.0	18.714	46.9	2.5	0.027
GROUP MEAN		57.5	22.1	38.4	10.5	6.4	61.3	17.133	4333	25.3	0.029
15-I(Ref)	12/4	75.5	3.6	4.8	12.0	0	0	18.725	303	1.6	0.040
15-II(Ref)	12/4	71.4	2.3	3.2	12.9	0	0	19.378	348	1.8	0.004
15-III(Ref)	12/4	19.5	0.9	4.6	1.7	0.6	35.3	7.597	91	1.2	0.002
15-IV(Ref)	12/4	53.8	0	0	7.7	0.6	7.8	16.114	1059	6.6	0.004
15-V(Ref)	12/4	58.4	1.1	1.9	10.5	0.3	2.9	18.543	45	0.2	0.034
GROUP MEAN		55.7	22.1	39.7	9.0	4.5	50.4	16.071	4896	30.5	0.033
27-I(Ref)	12/4	87.0	0.9	1.0	14.2	0.3	2.1	19.545	45	0.2	0.033
27-II(Ref)	12/4	81.0	5.9	0.7	14.2	1.2	8.5	19.303	514	2.7	0.036
27-III(Ref)	12/4	80.0	0.9	1.1	14.2	0.6	4.2	20.223	61	0.3	0.030
27-IV(Ref)	12/4	70.1	0.5	0.7	9.9	0	0	18.511	272	1.5	0.034
27-V(Ref)	12/4	74.2	1.4	0.2	12.9	0.6	4.7	19.421	227	1.2	0.036
GROUP MEAN		78.5	6.5	8.3	13.1	1.9	14.3	19.401	612	3.2	0.031

Mean and standard deviation calculated from duplicate analyses.

Dash indicates not determined.

 $V$  is coefficient of variation  $\times 100\%$ .

Reference Grid Square 15-III showed metal concentrations which were lower than those found at the other stations (with the exception of lead, cadmium, and arsenic). For example, manganese ranged from 341 to 560 mg/kg at Stations I, II, IV, and V, while at Station III, it was 224 mg/kg. At the four other stations, iron ranged from 16,114 to 19,378 mg/kg; 7,597 mg/kg was observed for Station III. Zinc, nickel, chromium, copper and mercury followed this pattern. These metals also showed some degree of variation among the values at Stations I, II, IV and V. Zinc levels at these stations varied from 53.8 to 75.5 mg/kg.

With the exception of lead, the samples from G.S. 27 showed little variation. The coefficients of variation for the analyses from the grid stations within the grid ranged from 3% to 8% for six of the metals. For nickel and copper they were 13% and 14%, respectively, and for lead it was 140%. The mean concentrations of metals in G.S. 27 are not significantly different from those in G.S. 2, as the standard deviations are such that the mean plus or minus one standard deviation overlap for all ten metals.

In general, heavy metal concentrations at Station III in G.S. 14, 15 and (for some metals) 12, had a lower concentration than was found at Stations I, II, IV and V. Some variation was also seen in metals at these other four stations.

Sediments collected in November and December (Table V-20) were compared to those collected before disposal (Figures V-13 through V-22). Heavy metal concentrations were generally comparable. The later samples did show lower chromium, nickel, and to a lesser degree, arsenic levels. Little change was noticed in the concentrations of other metals monitored.

Replicate sediment samples collected from the GBEC Disposal Site Buoy B on April 21, 1976, showed a wide range of concentrations of most metals analyzed (Table V-21). The highest coefficients of variation were found for mercury ( $V = 71\%$ ), nickel ( $V = 60\%$ ), lead ( $V = 57\%$ ), cadmium ( $V = 50\%$ ) and manganese ( $V = 46\%$ ). Smaller variation was seen in values of chromium, zinc, copper, iron and arsenic. The coefficients of variation for these metals ranged from 15 to 31%.

Metals analyses on a second set of replicates are shown in Table V-22. In this case the coefficients of variation show that the widest variation in the replicate analyses for metals is in the lead data ( $V = 52\%$ ). The next most varied data was that for cadmium ( $V = 43\%$ ). The variation in the other metals analyses was smaller. The range of coefficients of variation was 5 % to 33%. As a group, these data showed less variation than that obtained for the replicate from Buoy B (Table V-21).

Tables V-21 and V-22 show the coefficients of variation ( $V$ ) for the duplicate analyses of each replicate as well as for the mean of the analyses of all replicates (Column V). The coefficients of variation for the duplicate analyses were lower than for the ten or eleven replicates averaged together for almost all metals. This indicates that the variability seen in these analyses was due more to the nature of the sediment than to the processing and analysis of the samples.

In the case of the analyses of the Buoy B replicates, Table V-21, the coefficients of variation for the 10 replicate analyses were less than for the mean of all the replicates for all metals except zinc. For zinc, the

Table V-21  
 Total Heavy Metal Data: Galveston Bay Entrance Channel Disposal  
Site Buoy B Replicate Sediment Samples Collected April, 1976  
 (mg/kg)

Replicate Number	Mn			Cr			Cd			Ni			Pb		
	$\bar{x}$	SD	V(%)	$\bar{x}$	SD	V(%)	$\bar{x}$	SD	V(%)	$\bar{x}$	SD	V(%)	$\bar{x}$	SD	V(%)
1	154	24	15.6	4.1	0.4	9.8	0.8	0.1	12.5	1.3	0.4	30.8	<1	-	-
2	149	3	2.0	4.4	0.4	9.1	0.5	0	0	<0.5	0	0	<1	-	-
3	153	3	2.0	4.4	0.4	9.1	0.6	0	0	1.4	0.4	28.6	2.9	0.5	17.2
4	204	13	6.4	4.5	0.2	4.4	0.6	0.1	16.7	0.8	0.4	50.0	3.3	1.0	30.3
5	118	18	15.3	3.4	0.3	8.8	1.4	0.1	7.1	2.7	0	0	4.5	0.9	20.0
6	128	5	3.9	3.9	0.4	10.3	1.0	0.1	10.0	2.1	0	0	2.0	0.9	45.0
7	384	35	9.1	5.1	0.4	7.8	<0.5	-	-	0.8	0.4	50.0	<1	-	-
8	146	7	4.8	3.1	0	0	0.9	0	0	<0.5	0	0	<1	-	-
9	135	19	14.1	3.9	0.4	10.3	1.5	0.3	20.0	2.4	0.4	16.7	3.8	1.1	28.9
10	128	1	0.1	4.6	0	0	2.0	0.1	5.0	2.7	0	0	2.6	0.9	34.6
Column Mean	170			4.1			1.0			1.5			2.3		
" SD	79			0.6			0.5			0.9			1.3		
" V(%)	46.5			14.6			50.0			60.0			56.5		

(Continued)

Table V-21 (Concluded)

Replicate Number	Zn			Cu			Fe			Hg			As		
	$\bar{X}$	SD	V(%)	$\bar{X}$	SD	V(%)	$\bar{X}$	SD	V(%)	$\bar{X}$	SD	V(%)	$\bar{X}$	SD	V(%)
1	19.4	9.3	47.9	<1	0	0	3814	18	0.5	0.015	0.007	46.7	0.4	0	0
2	11.5	1.2	10.4	<1	-	-	4060	366	9.0	0.055	0	0	0.3	0	0
3	21.2	9.3	43.9	1.7	0.1	5.9	3929	305	7.8	0.010	0	0	0.5	0	0
4	14.0	1.3	9.3	1.5	0.3	20.0	5508	475	8.6	0.020	0	0	0.4	0	0
5	10.8	0	0	1.6	0.2	12.5	3338	291	8.7	0.010	0	0	0.4	0	0
6	11.6	0.7	6.0	1.7	0	0	3569	37	1.0	0.033	0.018	54.5	0.3	0	0
7	17.2	5.2	30.2	1.7	0.4	23.5	7694	714	9.3	0.015	0.007	46.7	0.5	0.1	20.0
8	10.8	0.2	1.9	1.2	0	0	4345	0	0	0.010	0	0	0.5	0.1	20.0
9	14.6	2.1	14.4	1.6	0	0	3572	279	7.8	0.020	0	0	0.4	0	0
10	10.7	0.6	5.6	2.3	0.5	21.7	3338	53	1.6	0.050	0.007	14.0	0.4	0	0
Column Mean	14.2			1.5			4317			0.024			0.4		
" SD	3.9			0.4			1347			0.017			0.1		
" V(%)	27.5			26.7			31.2			70.8			25.0		

Sample mean and standard deviation calculated from duplicate analyses.

Dash (-) indicates not determined.

V is coefficient of variation X 100%.

Table V-22  
 Total Heavy Metal Data: Galveston Bay Entrance Channel Disposal  
Site Reference G.S. 15 Replicate Sediment Samples Collected April, 1976  
 (mg/kg)

Replicate Number	Mn			Cr			Cd			Ni			Pb		
	$\bar{X}$	SD	V(%)	$\bar{X}$	SD	V(%)	$\bar{X}$	SD	V(%)	$\bar{X}$	SD	V(%)	$\bar{X}$	SD	V(%)
1	392	25	6.4	18.9	1.0	5.3	<0.5	-	-	8.6	0	0	6.3	0	0
2	371	48	12.9	16.6	2.3	13.9	1.2	0.1	8.3	7.3	0.4	5.4	4.5	0.9	20.0
3	418	18	4.3	22.8	1.9	8.3	1.0	0.1	10.0	9.7	0.8	8.2	9.2	2.3	25.0
4	325	8	2.5	13.0	0.4	2.1	1.4	0.1	7.1	7.3	0.4	5.4	4.8	1.3	27.1
5	360	14	3.9	15.4	0	0	<0.5	-	-	7.6	1.6	21.1	14.8	1.0	6.8
6	347	3	0.9	17.3	2.5	14.5	0.9	0	0	8.9	0.4	4.5	2.9	1.3	44.8
7	375	14	3.7	15.3	0.9	5.9	<0.5	-	-	10.7	2.8	26.2	15.5	0	0
8	333	27	8.1	14.4	0.9	6.3	<0.5	-	-	8.4	1.2	14.3	18.3	0	0
9	311	54	17.4	13.3	0.6	4.5	<0.5	-	-	10.7	0.4	3.7	16.2	1.0	6.2
10	366	17	4.6	16.8	0.6	3.6	0.6	0.2	33.3	10.1	0.4	7.7	18.3	0	0
11	410	19	4.6	22.1	1.2	5.4	<0.5	-	-	12.4	0.4	3.2	14.1	0	0
Column Mean	364			16.9			0.7			9.2			11.4		
Column SD	34			3.3			0.3			1.6			5.9		
Column V(%)			9.3			19.5			42.9			17.4			51.8

(Continued)

Table V-22 (Concluded)

Replicate Number	Zn			Cu			Fe			Hg			As		
	$\bar{x}$	SD	V(%)	$\bar{x}$	SD	V(%)	$\bar{x}$	SD	V(%)	$\bar{x}$	SD	V(%)	$\bar{x}$	SD	V(%)
1	65.8	15.6	23.7	8.1	0.5	6.2	17,939	80	0.4	0.070	0	0	1.0	0.1	10.0
2	46.0	12.5	27.2	6.5	1.2	18.5	16,414	279	1.7	0.060	0	0	0.8	0.1	12.5
3	60.3	6.7	11.1	8.2	0.6	7.3	7,713	359	4.7	0.070	0	0	0.9	0	0
4	37.4	0	0	4.7	0.1	2.1	15,693	20	0.1	0.055	0	0	0.7	0.1	14.3
5	44.2	1.5	3.4	7.5	0.3	4.0	17,837	304	1.7	0.070	0	0	0.6	0	0
6	46.3	1.6	3.4	6.7	0	0	16,315	60	0.4	0.070	0	0	0.8	0.1	12.5
7	47.0	2.1	4.5	8.4	0.9	10.7	17,988	30	0.2	0.060	0	0	0.5	0	0
8	39.4	2.4	6.1	6.9	1.2	17.4	17,730	30	0.2	0.055	0	0	0.5	0	0
9	37.3	10.3	27.6	6.5	1.1	16.9	17,364	1,641	9.5	0.060	0	0	0.4	0	0
10	43.5	1.9	4.4	7.2	0.2	2.8	17,515	40	0.2	0.060	0	0	0.5	0.1	20.0
11	52.8	3.0	5.7	8.2	0.2	2.4	18,976	213	1.1	0.088	0.025	28.4	0.4	0	0
Column Mean	47.3			7.2			17,411						0.065	0.6	
Column SD	9.1			1.1			929						0.010	0.2	
Column V(%)	19.2			15.3			5.3						15.4	33.3	

Sample mean and standard deviation calculated from duplicate analyses.

Dash (-) indicates not determined.

V is coefficient of variation X 100%.

column mean was  $V = 28\%$ . There were three replicate  $V$ 's greater than 27.5%. This may also be seen in the coefficients of variation for zinc and copper in the analyses of the G.S. 15 replicate, seen in Table V-22. There was also one replicate  $V$  greater than the Column  $V$  in the iron and mercury data for the G.S. 15 replicates.

The coefficient of variation of the duplicate analyses may be considered to be indicative of variability in the data due to processing and analyses of the individual samples, and the coefficient of variation for the mean of the replicate analyses may be considered to indicate variability within the sediment itself. The values of the coefficients for these data indicate that the variability encountered is most probably due to the nature of the sediment itself rather than to the processing and analyses.

#### Interstitial Water and Ammonium Acetate-Extractable Fraction

Results of IW analysis and ammonium acetate extraction analysis are shown in Tables V-23 and V-24. Like the dredging site sediments, these sediments show higher IW metal concentrations, except for iron, than did the overlying waters. Zinc showed the greatest variation, with levels ranging from 45 to 2400  $\mu\text{g/l}$ . Arsenic and chromium were below detection limits, while cadmium was seen to vary from 4.2 to 89.2  $\mu\text{g/l}$  in IW, and from less than 0.3 to 2.9 mg/kg dry weight for the ammonium acetate-extracted fraction. Manganese levels were determined, but upon reexamination the data were found to be unreliable and have not been included. Generally, it can be said that the sediments contained varying amounts of metals and that there were no obvious trends in the grid squares. Concentrations in IW seemed independent of those in overlying waters.

Table V-23  
**Soluble Metals in Interstitial Water from Galveston Bay**  
Entrance Channel Disposal Site Sediments

Sampling Location	Date Collected (1975)	Cr	Cd	Ni*	Pb	Zn	Cu*	Fe	As
G.S. 2-III	7/14	< 1.0	11	-	120	2400	-	6.5	-
G.S. 11	4/16	< 1.0	67.6	-	70	110	-	216	<2.0
G.S. 15 (Ref)	7/14	< 1.0	11	3.5	110	45	13	4.0	-
G.S. 21	4/16	< 1.0	89.2	10.0	35	100	20	<1.0	<2.0
G.S. 23	4/17	< 1.0	55.6	7.0	<2.0	88	8	510	<2.0
G.S. 27 (Ref)	7/24	< 1.0	8.5	4.0	95	800	30	7.0	-
Buoy D	8/26	< 1.0	10	-	60	66	-	2.0	-
Buoy D	8/26	< 1.0	14	-	100	60	-	<1.0	-
Buoy D	8/26	< 1.0	4.2	-	110	60	-	<1.0	-

Dash (-) indicates data not available.

\* = MIBK extracted.

Table V-24  
Heavy Metals in Ammonium Acetate-Extractable Fraction:  
Galveston Bay Entrance Channel Disposal Site Sediments  
(mg/kg)

Sampling Location	Date Collected (1975)	Cr	Cd	Pb	Zn	Fe
Buoy D	8/26	<0.3	<0.3	<0.5	6.4	19.5
Buoy D	8/26	<0.3	0.8	<0.5	9.1	27.8
Buoy D	8/26	<0.3	<0.3	<0.5	18.6	15.5
G.S. 2-III	7/14	<0.3	2.9	<0.5	4.8	11.9
G.S. 15 (Ref)	7/14	<0.3	0.7	<0.5	12.8	36.2
G.S. 27 (Ref)	7/14	<0.3	0.7	<0.5	9.2	25.3

Relationships between the metal content of sediments and metal concentrations in the IW were examined. No relationships were noted for those samples analyzed, nor was any relationship observed between interstitial water heavy metal concentrations and ammonium acetate-leachable metal concentrations.

Heavy Metal Content of Selected Disposal Site Polychaetes

Polychaetes obtained by a box dredge from the GBEC Disposal Site area were analyzed for selected heavy metals. Due to the very small weight of each organism, composites were analyzed. The organisms were not fed for 96 hours to purge their intestinal tracts of metals. The water in which the organisms were purged was changed daily to minimize reingestion of purged materials. Thus, the metal content that was determined for these organisms essentially represented the metal content of the tissue. Composite dry weights were less than 0.9 g. Each dried sample was digested in  $\text{HNO}_3$  and  $\text{HClO}_4$  which enabled determination of total heavy metal content.

The polychaetes were taken from the disposal site at Buoys C and D. In addition, two sets of samples were taken southeast of the GBEC lighthouse jetty. The samples taken near Buoy D were taken prior to disposal in this region and therefore represent "reference" samples. The results of analysis of polychaete samples are listed in Table V-25. Examination of the data shows that there is no readily discernible pattern in the heavy metal content of the polychaetes analyzed. The only element that showed any apparent significant change as a result of purging was iron. It appears that there is no relationship between the heavy metal content of the polychaetes and that of the sediments in which they live, based

Table V-25  
Total Heavy Metal Content of Polychaetes from Galveston  
Bay Entrance Channel Disposal Site Area

Sampling Location and Date of Collection	Concentration on Dry Weight Basis								
	Mn	Cr	Cd	Ni	Pb	Zn	Cu	Fe	Hg
Reference-Nonpurged September 12, 1975	35	5	5	< 5	10	258	20	807	-
Reference-Purged September 8, 1975	20	< 3	< 3	< 7	< 7	373	72	413	-
Buoy C-Nonpurged September 12, 1975	32	7	5	<10	< 9	136	294	388	-
Buoy D-Purged August 28, 1975	6	1	5	20	5	111	70	601	0.02

Dash (-) indicates no analysis made.

on the very limited sampling done here. These results are not surprising; others have found little or no relationship between the heavy metal content of benthic organisms and the sediments in which they live.<sup>2</sup> It is becoming increasingly apparent that factors other than total heavy metal content of the sediments play a major role in determining the heavy metal content of organisms.

#### Nitrogen Compounds

##### Dredging Sites

Results of the organic nitrogen analysis for the sediments collected from the dredging sites are presented in Table V-26. The Kjeldahl nitrogen concentrations ranged from 75 mg N/kg at Buoy 7 to 1820 mg N/kg in the TCC 3 sample.

##### Disposal Site

Pre-disposal. Table V-27 presents the results of organic N and ammonium analysis of GBEC Disposal Site sediments collected before disposal operations. The percent dry weight data indicated a slightly higher sand content in the samples from the north and west sides of the disposal site. The organic N content of sediments from this grid varied from 228 to 1062 mg N/kg; concentrations in the southeast quarter of the disposal grid (Figure V-23) were somewhat higher. Ammonium concentrations ranged from 21 to 233 mg N/kg and were lower in the central portion of the disposal area than around the periphery (Figure V-24).

The results of the nitrogen compound analysis of G.S. 2 sediments are presented in Table V-28. Some disposal of dredged sediments had taken place there during early May. The organic N concentrations ranged from 157 to 648 mg N/kg, and ammonium varied from 32 to 86 mg N/kg, with the lower

Table V-26  
Kjeldahl Nitrogen Data: Galveston Bay Entrance Channel  
and Texas City Channel Turning Basin Sediments

Sampling Location	Date Collected (1975)	Kjeldahl Nitrogen (mg N/kg)	
		$\bar{X}$	SD
TCC 1	3/28	1670	47
TCC 2	3/28	643	12
TCC 3	3/28	1820	432
TCC 4	9/20	1366	8
TCC 5	9/20	654	35
TCC 6	9/20	1249	116
GBEC Buoy 1	6/11	1325	211
GBEC Buoy 7	4/18	75	16
GBEC Buoy 9	4/12	152	1
GBEC Buoy 11	4/12	213	21

Mean and standard deviation calculated from duplicate analyses.

concentrations in the post-disposal sample collected at G.S. 2-III on June 11. This magnitude of variability even with a small area is not unusual for sediments.

Sediment samples from a reference area north of the GBEC were analyzed for organic N and ammonium; the data are presented in Table V-29. The ammonium concentrations ranged from 31 to 51 mg N/kg, but the organic N concentrations varied considerably, ranging from 179 to 467 mg N/kg.

The results of the nitrogen compound analysis of GBEC Disposal Site sediments collected during July and August are presented in Table V-30. From the data it appears

Table V-27  
Nitrogen Data: Galveston Bay Entrance Channel  
Disposal Site Sediments

Sampling Location (Grid Square)	Date Collected (1975)	Organic Nitrogen (mg N/kg)		Ammonium (mg N/kg)	
		$\bar{X}$	SD*	$\bar{X}$	SD**
2	4/17	614	23	67	11
3	4/18	457	65	113	23
4	4/16	246	35	76	11
6	4/17	645	38	70	9
7	4/16	454	27	40	13
8	4/17	228	27	32	5
9	4/17	468	25	30	21
10	4/17	305	77	30	2
11	4/16	442	29	34	10
12	5/03	451	14	23	8
13	4/17	670	32	54	17
14	4/16	510	-	46	2
15 (Ref)	4/17	228	-	97	9
16	4/17	350	-	44	4
17	4/29	461	-	21	4
18	4/16	553	47	22	31
19	5/03	609	106	67	13
20	5/16	673	240	76	30
21	4/17	802	147	76	4
22	4/17	550	60	86	11
23	4/17	650	8	62	4
24	4/29	772	21	89	0
25	4/16	944	128	64	36
26	5/03	493	80	127	69
27 (Ref)	5/16	1062	24	89	3
28	4/16	481	-	233	-

Dash (-) indicates data not available.

\*Standard deviation calculated from triplicate analyses.

\*\*Standard deviation calculated from duplicate analyses.

FIGURE V-23  
MEAN ORGANIC N CONCENTRATIONS IN GBEC  
DISPOSAL SITE SEDIMENT SAMPLES  
(MG N/KG)

	2	3	4	5	6	7
1	614 SD=23	457 SD=65	246 SD=35		645 SD=38	454 SD=27
8	9 SD=27	10 SD=25	11 SD=77	12 SD=29	13 SD=14	14 SD=3.2
15	228 SD=27	468 SD=25	305 SD=77	442 SD=29	451 SD=14	510 SD=3.2
16	16 SD=27	17 SD=25	18 SD=77	19 SD=29	20 SD=14	21 SD=3.2
22	228 SD=27	350 SD=25	461 SD=77	553 SD=29	609 SD=106	802 SD=24.0
23	23 SD=6.0	24 SD=8	25 SD=21	26 SD=128	27 SD=80	28 SD=24
550	550 SD=6.0	772 SD=8	944 SD=21	493 SD=128	1062 SD=80	481 SD=24

SEE FIGURE V-8 FOR EXPLANATION OF TERMS.

← 0.5 MI →

FIGURE V- 24  
 MEAN AMMONIUM CONCENTRATIONS IN GBEC  
 DISPOSAL SITE SEDIMENT SAMPLES  
 (MG N/KG)

	2	3	4	5	6	7
1	67 SD=11	113 SD=23	76 SD=11		70 SD=9	40 SD=13
8	9 SD=5	10 SD=21	11 SD=2	12 SD=10	13 SD=.8	14 SD=.17
32	30 SD=5	30 SD=21	34 SD=2	23 SD=10	54 SD=.8	46 SD=.2
15	16 SD=9	17 SD=4	18 SD=4	19 SD=31	20 SD=13	21 SD=30
97	44 SD=9	21 SD=4	22 SD=4	67 SD=31	76 SD=30	76 SD=4
22	23 SD=11	24 SD=4	25 SD=0	26 SD=36	27 SD=69	28 SD=3
						← 0.5 MI →

SEE FIGURE V- 8 FOR EXPLANATION OF TERMS.

Table V-28  
Nitrogen Data: Galveston Bay Entrance Channel  
Grid Square 2 Sediments

Sampling Location (Grid 2)	Date Collected (1975)	Organic Nitrogen (mg N/kg)		Ammonium (mg N/kg)	
		$\bar{X}$	SD*	$\bar{X}$	SD**
2-III	5/6	648	44	66	14
2-Va	5/6	235	63	33	5
2-IVa	5/6	292	47	46	1
2-IIa	5/6	458	47	86	6
2-Ia	5/6	290	25	42	8
2-III	6/11	157	44	32	4

(Post-Disposal)

\*Standard deviation calculated from triplicate analyses.

\*\*Standard deviation calculated from duplicate analyses.

Table V-29  
Nitrogen Data: Reference Area Sediment Samples on  
North Side of Galveston Bay Entrance Channel  
(May 13, 1975)

Sampling Location	Organic Nitrogen (mg N/kg)		Ammonium (mg N/kg)	
	$\bar{X}$	SD*	$\bar{X}$	SD**
a	358	-	40	4
b	467	9	46	3
c	179	36	31	8
d	223	26	38	13
e	412	37	48	7
f	447	90	45	22
g	262	40	48	1
h	206	-	51	12

Dash (-) indicates data not available.

\*Standard deviation calculated from triplicate analyses.

\*\*Standard deviation calculated from duplicate analyses.

Table V-30  
Nitrogen Data: Galveston Bay Entrance Channel Disposal  
Site Sediments July and August, 1975 (Pre-Disposal)

Sampling Location	Date Collected (1975)	Ammonium (mg N/kg)		Organic Nitrogen (mg N/kg)	
		$\bar{X}$	SD	$\bar{X}$	SD
Buoy D-III	8/26	63	20	479	27
Buoy D-III	8/26	35	0	546	185
Buoy D-III	8/26	21	2	283	27
Buoy C-III	8/26	94	14	656	240
Buoy C-III	8/26	65	3	-	-
G.S. 2-II	7/14	26	1	51	24
G.S. 2-III	7/14	24	9	196	26
G.S. 2-III	7/14	56	16	660	133
G.S. 2-V	7/14	44	5	341	31
G.S. 12-I	7/21	35	3	281	50
G.S. 14-I	7/22	54	22	397	60
G.S. 14-V	7/22	104	23	234	42
G.S. 15-I (Ref)	7/23	42	4	538	119
G.S. 27-II (Ref)	7/24	74	28	858	157
G.S. 27-I (Ref)	7/24	87	7	927	46

Standard deviation calculated from duplicate analyses.

Dash (-) indicates no data available.

that concentrations of nitrogen compounds varied considerably throughout the disposal site grids (e.g., ammonium concentrations in the disposal site ranged from 21 to 104 mg N/kg; organic N ranged from 51 to 927 mg N/kg). Even at one station (Grid 2-III), ammonium and organic N concentrations of one sample were two and three times, respectively, those of the other sample.

Post-disposal. The results of ammonium analysis of disposal site sediments collected on September 10, 1975, are presented in Table V-31. Sediments collected from different locations in the Buoy C grid did not show much variation in ammonium concentrations. Considerable variation was observed in samples collected near Buoy D and especially Reference Grid Square 15, indicating the high variability of the system. The data for Buoy C in comparison with corresponding pre-disposal data indicate a statistically significant difference. It is felt, however, that differences of this magnitude are well within specific site differences over time for sediments of this type. Therefore, while statistically significant, the differences are not likely to be ecologically significant. (See Discussion, Part VI.) For Buoy D and Reference G.S. 15 sediment concentrations, no comparison could be made because of the extreme variation in results.

The ammonium and organic N data for the sediments collected October 10 from selected sites in the disposal site are presented in Table V-32. The ammonium content in the sediment was found to be rather low in comparison to the earlier ammonium content (Tables V-30 and 31). The organic N concentration ranged from 105 to 672 mg N/kg. Considerable variation in organic N and ammonium concentrations was observed in samples from the same general location. There was wide variation between samples at a particular site (33 and 102 mg N/kg at reference sites near Buoy C). Reference and mound samples showed higher concentrations compared to each other at Buoy C and Buoy B, respectively.

Another series of sediment samples were collected from the GBEC Disposal Site area during

Table V-31  
Ammonium Data: Galveston Bay Entrance Channel  
Disposal Site Sediments, September 10, 1975  
(Post-Disposal)

Sampling Location	Ammonium (mg N/kg)	
	$\bar{X}$	SD
Buoy C-I	47	11
Buoy C-II	53	24
Buoy C-III	50	9
Buoy C-IV	58	5
Buoy D-I	72	52
Buoy D-2	99	25
Buoy D-3	60	8
Buoy D-4	40	37
Buoy D-5	42	5
G.S. 15-B (Ref)	55	30
G.S. 15-C (Ref)	120	8
G.S. 15-D (Ref)	8	-

Standard deviation calculated from duplicate analyses.

Dash (-) indicates only one reading was taken.

late November and early December after cessation of dredged material disposal in this area. Samples were collected from different parts of Grid Squares 2, 12, 14, 15 (reference area) and 27 (reference area). The results of ammonium and organic N analyses are presented in Table V-33.

Organic N concentrations in Buoy C sediments ranged from 13 to 814 mg N/kg with the lowest concentration in the middle of the square. However, the same pattern was not observed for ammonium, which ranged from 2.1 to 91 mg N/kg with the high concentration in the middle. Organic N

Table V- 32  
Post-Disposal Organic Nitrogen and Ammonium Data:  
Galveston Bay Entrance Channel Disposal Site  
October 10, 1975

Sampling Location	Organic Nitrogen (mg N/kg)		Ammonium (mg N/kg)	
	$\bar{X}$	SD	$\bar{X}$	SD
<b>Buoy B</b>				
Mound <sub>2</sub>	259	13	39	9
Ref. <sub>1</sub>	301	28	43	8
Mound <sub>1</sub>	229	80	42	8
Ref. <sub>2</sub>	179	2	21	2
<b>Buoy C</b>				
Ref. <sub>2</sub>	672	86	33	15
Mound <sub>2</sub>	105	18	10	4
Mound <sub>1</sub>	131	26	15	2
Ref. <sub>1</sub>	651	56	102	28
<b>Buoy D</b>				
Ref. <sub>2</sub>	428	73	24	4
Ref. <sub>1</sub>	493	61	39	8
Mound <sub>1</sub>	272	17	29	1
Mound <sub>2</sub>	213	38	33	0
G.S. 15-III (Ref)	463	32	26	0
G.S. 15-III (Ref)	421	31	33	5
G.S. 15-III (Ref)	337	15	63	11
G.S. 15-III (Ref)	532	46	56	7
G.S. 27-II (Ref)	638	31	38	1
G.S. 27-III (Ref)	577	1	51	0

Standard deviation calculated from duplicate analyses.

Table V-33  
Ammonium and Organic N Data  
Post-Disposal Galveston Bay Entrance Channel  
Disposal Site Sediments  
(mg N/kg)

Sample Location (1975)	Organic Nitrogen	Ammonium
<hr/>		
November 25		
Buoy B-I	222	24
II	36	34
III	435	101
IV	140	68
V	576	66
December 3		
Buoy C-I	692	91
II	568	63
III	13	31
IV	647	2.1
V	814	55
December 5		
Buoy D-I	270	22
II	789	71
III	324	35
IV	881	76
V	507	48
December 4		
G.S. 15-I (Ref)	1633	139
G.S. 15-II (Ref)	< 1	96
G.S. 15-III (Ref)	26	27
G.S. 15-IV (Ref)	461	65
G.S. 15-V (Ref)	553	50

(Continued)

Table V-33 (Concluded)

Sample Location (1975)	Organic Nitrogen	Ammonium
G.S. 27-I (Ref)	1227	71
G.S. 27-II (Ref)	644	77
G.S. 27-III (Ref)	824	96
G.S. 27-IV (Ref)	735	109
G.S. 27-V (Ref)	829	59

and ammonium in Buoy B sediments ranged from 36 to 576 mg N/kg and 24 to 101 mg N/kg, respectively. Considerable variation in organic N and ammonium concentration had also been observed in G.S. 2 sediments before disposal operations began. Near Buoy D ammonium and organic N concentrations ranged from 22 to 76 mg N/kg and 270 to 881 mg N/kg, respectively.

Replicate sediment samples collected near Buoy B on April 21, 1976, were analyzed for ammonium and organic N concentration; the data are shown in Table V-34. The replicates showed that there was little variation in ammonium concentration which ranged from 4.0 to 9.8 mg N/kg. The organic N values were much more variable and ranged from 18 to 375 mg N/kg. It was also observed that in this set of samples, organic N and ammonium concentrations were lower than in the samples collected in November, 1975. These results again indicated the variability in organic N concentration within a small place.

Results of ammonium and organic N analyses for the replicate sediment samples collected in Reference G.S. 15 are presented in Table V-35. Ammonium concentrations observed ranged from 78 to 145 mg N/kg. These concentrations showed approximately the same range of values between

Table V- 34  
Ammonium and Organic N Data  
Post-Disposal Replicate Sediment Samples  
Collected Near Buoy B, April, 1976  
(mg N/kg)

Replicate Number	Organic Nitrogen		Ammonium		*SD
	$\bar{X}$	SD	$\bar{X}$	SD	
1	204	36	5.4	0	
2	45	-	6.6	0.4	
3	224	16	4.9	0.8	
4	216	-	6.9	0.5	
5	375	-	4.0	0.1	
6	18	9	5.0	0.7	
7	26	-	4.5	0.8	
8	28	3	4.6	0.2	
9	52	-	9.8	1.1	
10	62	-	4.4	0.3	

\* Standard deviation calculated from duplicate analyses.  
Dash (-) indicates data not available.

the sampling periods. However, the mean of the April values was considerably higher than the mean of the December values. The high variability of the values obtained at this site precludes any statistically significant difference in these values.

The replicate sediment samples from near Buoy B and Reference G.S. 15 were mixed together. Ten subsamples were taken and analyzed to determine ammonium and total Kjeldahl N concentrations. These tests were designed to

Table V-35  
Ammonium and Organic N Data: Post-Disposal  
Replicate Sediment Samples Collected from  
Reference Grid Square 15, April, 1976  
(mg N/kg)

Replicate Number	<u>Organic Nitrogen</u> $\bar{X}$	<u>Ammonium</u> $\bar{X}$	
		SD*	
1	516	78	2
3	710	138	2
4	868	135	11
5	1083	118	4
7	754	117	10
10	962	109	16
11	1205	117	20
13	121	124	3
16	252	145	12
21	1001	116	1
26	344	141	2

\*Standard deviation calculated from duplicate analyses.

check the analytical variability. Since subsamples were taken separately for  $\text{NH}_4^+$  and TKN analyses, a single sample could not be analyzed for both TKN and ammonium. Therefore, since ammonium was not analyzed for certain subsamples, organic N (TKN minus ammonium) could not be calculated. Percent dry weight values used for calculation were derived from the grand mean of the individual means of sediments from each site.

The data presented in Tables V-36 and V-37 show TKN and ammonium ranged from 32 to 182 and 7.4 to 17.4 mg N/kg, respectively, near Buoy B and from 59 to 1040 and 38 to 106 mg N/kg in Reference Grid Square 15, respectively. TKN concentrations decreased in the pooled

Table V-36  
Ammonium and Total Kjeldahl Nitrogen Data:  
Pooled Buoy B Sediments  
(mg N/kg)

Replicate Number	Total Kjeldahl Nitrogen	Ammonium
1	32	13.1
2	128	17.4
3	112	13.5
4	74	9.3
5	182	10.1
6	122	7.9
7	137	9.3
8	131	9.4
9	111	9.1
10	125	7.4
Column Mean	115	10.6
SD	40	3.1

Table V-37  
Ammonium and Total Kjeldahl Nitrogen Data:  
Pooled Sediments from Reference Grid Square 15  
(mg N/kg)

Replicate Number	Total Kjeldahl Nitrogen	Ammonium
1	500	38
2	580	48
3	964	77
4	311	106
5	59	85
6	767	95
7	376	89
8	212	92
9	1040	100
10	594	101
Column Mean	540	83
SD	317	23

sediment compared to the individual replicates. It appears that because pooling required excessive handling and alternate freezing and thawing of these sediments, the concentrations of TKN and ammonium were low. The analytical reproducibility was satisfactory for all replicate sediment samples, except TKN results in Reference Grid Square 15 samples.

#### Interstitial Water and Cesium Chloride-Extractable Fraction

Results of interstitial water (IW) analysis and cesium chloride (CsCl) fraction analysis for ammonium are presented in Tables V-38 and V-39. The ammonium concentrations of the interstitial water ranged from 3.4 to 32.9 mg N/l. The range was 7.0 to 66.3 mg N/kg based on sediment dry weight for the CsCl-extractable fraction. The ammonium content in TCCTB interstitial water was high; sample concentrations decreased from the upper end of the turning basin (TCC 1) down the channel. Concentrations in the GBEC Disposal Site were highest in G.S. 2, 15 (reference area), 21 and 23, but lower than TCCTB sediments.

Only six samples were CsCl-extracted. The limited data (found in Table V-39) suggest that ammonium concentrations in the extract appeared to be related to the IW ammonium content. The ammonium data for interstitial water in post-disposal samples are presented in Table V-40. The concentrations ranged from 3.8 to 18.4 mg N/l. The samples from GBEC Disposal Site Buoys B and D had the highest and lowest concentrations, respectively. The results for ammonium in the CsCl-extractable fraction of the sediments are presented in Table V-41. Concentrations ranged from 5.5 to 16.8 mg N/kg. The highest value was from Buoy B and the lowest from Buoy D. Comparing the data

Table V- 38  
Pre-Disposal Ammonium Content in Interstitial Water  
For Selected Sediment Samples From The  
Galveston Study Area

Sampling Location	Date Collected (1975)	Ammonium (mg N/l)	
		$\bar{X}$	SD
TCC 1	4/12	32.9	4.8
TCC 2	4/12	23.6	1.0
TCC 3	4/12	21.3	2.1
GBEC Buoy 9	4/12	6.0	0.4
GBEC Buoy 11	4/12	7.4	0.2
G.S. 2	6/11	22.9	0.9
G.S. 2-III	7/14	9.5	0.2
G.S. 11	4/16	7.1	0.5
G.S. 15 (Ref)	7/14	21.6	1.7
G.S. 21	4/16	13.2	0.4
G.S. 23	4/17	13.2	0.5
G.S. 27 (Ref)	7/24	6.0	0.4
Buoy D-III	8/26	5.8	0.5
Buoy D-III	8/26	4.9	0.2
Buoy D-III	8/26	3.4	0.2

Standard deviation calculated from triplicate analyses.

in Tables V-39 and V-41 with those of the pre-disposal data, it can be seen that the ammonium concentrations in the CsCl-extractable fraction of the sediments apparently decreased after disposal. The cause of this decrease is unknown at this time.

Table V-39  
Pre-Disposal Ammonium Content in the CsCl-Extractable  
Fraction for Selected Sediments from the Galveston  
Bay Entrance Channel Disposal Site

Sampling Location (GBEC Disposal Site)	Date Collected (1975)	Ammonium (mg N/kg)	
		$\bar{X}$	SD
G.S. 2-III	7/14	10.6	0
G.S. 15 (Ref)	7/14	66.3	0.5
G.S. 27 (Ref)	7/24	27.4	1.4
Buoy D-III	8/26	22.4	0.4
Buoy D-III	8/26	14.9	0.6
Buoy D-III	8/26	7.0	0.3

Standard deviation calculated from triplicate analyses.

Table V- 40  
Ammonium Data: Post-Disposal Galveston Bay Entrance  
Channel Disposal Site Interstitial Water  
Sediment Samples, October 10, 1975

Sampling Location	Ammonium (mg N/l)	
	$\bar{X}$	SD
Buoy B		
Ref <sub>2</sub>	18.4	0.4
Buoy C		
Ref <sub>1</sub>	7.5	0.3
Buoy C		
Ref <sub>1</sub>	5.4	0.2
Buoy D		
Mound <sub>2</sub>	3.8	0.0
G.S. 15-III (Ref)	8.2	0.0
G.S. 27-III (Ref)	4.9	0.3

Mean and standard deviation calculated from triplicate analyses.

Table V-41

Ammonium Data: Post-Disposal Galveston Bay Entrance  
Channel Disposal Site CsCl-Extractable Fraction  
 October 10, 1975

Sampling Location	Ammonium (mg N/kg)* <u>X</u>
Buoy B Ref <sub>2</sub>	16.8
Buoy C Ref <sub>1</sub>	13.8
Buoy C Ref <sub>1</sub>	7.0
Buoy D Mound <sub>2</sub>	5.5
G.S. 15-III (Ref)	9.1
G.S. 27-III (Ref)	3.5

\*Single analysis except for Buoy B which had a duplicate.  
 The standard deviation was 0.9.

Phosphorus CompoundsDredging Sites

Total P content in the sediments in the GBEC and TCCTB is presented in Table V-42. The total P content in TCCTB sediment ranged from 473 to 1468 µg P/g. These concentrations were about four to fourteen times greater than those found in GBEC sediments. Concentrations in the GBEC ranged from 104 to 247 µg P/g; Buoy 11 sediments contained the greatest phosphorus concentration. There was no pattern for phosphorus content in the sediment proceeding seaward from Buoy 11, however.

Table V-42  
Pre-Disposal Total Phosphorus Content for Galveston Bay  
Entrance Channel and Texas City Channel  
Turning Basin Sediment Samples

Sampling Location	Date Collected	Phosphorus Content ( $\mu\text{g P/g}$ )	
		X	SD
GBEC Buoy 1	6/11	136	4
GBEC Buoy 5	6/11	104	-
GBEC Buoy 7	4/18	166	-
GBEC Buoy 9	4/12	111	2
GBEC Buoy 11	4/18	247	4
TCC 1	4/12	750	70
TCC 2	4/12	473	59
TCC 3	4/12	644	23
TCC 4	9/20	1468	34
TCC 5	9/20	937	7
TCC 6	9/20	1232	14

Standard deviation calculated from triplicate analyses.

Dash (-) indicates only one analysis made.

Table V-43  
Soluble Orthophosphate for Interstitial Water in Galveston  
Bay Entrance Channel and Texas City Channel Turning Basin  
(April 12, 1975)

Sampling Location	Soluble Ortho P (mg P/l)	
	X	SD
TCC 1	16.3	0.23
TCC 2	7.65	0.16
TCC 3	0.3	0
GBEC Buoy 11	0.05	0.002
GBEC Buoy 9	0.17	0.04

Standard deviation based on duplicate analyses.

Soluble ortho P concentrations in GBEC and TCCTB interstitial water are presented in Table V-43. In the Texas City Channel, IW concentrations ranged from 16.3 to 0.3 mg P/l. The farther seaward the samples, the less the concentration of soluble ortho P. This was not the pattern found with total P content in the sediment. The interstitial water soluble ortho P concentrations at GBEC Buoys 11 and 9 were 0.05 mg P/l and 0.17 mg P/l, respectively. The overlying water at Buoy 9 had a mean soluble ortho P concentration of 0.05 mg P/l.

#### Disposal Site

Pre-disposal. The total phosphorus content of the sediment in the disposal area before disposal is presented in Figure V-25. The total P content ranged from 60  $\mu\text{g}$  P/g sediment in G.S. 7 to 699  $\mu\text{g}$  P/g sediment in G.S. 24. Based on the data obtained before and after the May disposal in G.S. 2, total phosphorus in the sediment was reduced by 50 percent after disposal. There is no apparent pattern of phosphorus content in the disposal area sediment.

Tables V-44 and V-45 present the soluble ortho P content in interstitial water and in the ammonium acetate-extractable fraction of selected sediment samples from the disposal area. In general, IW soluble orthophosphate was greater than the highest concentrations found in the water column.

Post-disposal. Table V-46 presents the ortho P concentrations in the interstitial water in the GBEC Disposal Site sediments on October 10, 1975. Concentrations range from 1.6 mg P/l to 6.9 mg P/l. The considerable variation in the concentrations can be seen in Buoy C replicate sediment concentrations.

FIGURE V-25  
 MEAN TOTAL PHOSPHORUS CONTENT OF SEDIMENT IN GBEC DISPOSAL SITE  
 (MG P/KG SEDIMENT)  
 (APRIL 1975)

	2	3	4	5	6	7
1	110*	397			696	60
SD=1	SD=3	SD=4		SD=3	SD=3	
295	295	10	11	12	13	14
8	9					
394	141	216	293	417**	109	279
SD=30	SD=11	SD=4	SD=4	SD=0	SD=4	SD=2
15	16	17	18	19	20	21
530	224	456	381	479**	151	326
SD=0	SD=14***	SD=12	SD=1***	SD=3	SD=3	SD=3
22	23	24	25	26	27	28
392	280	699	170	110**	579	195
SD=83***	SD=20***	SD=4***	SD=4	SD=1	SD=15	SD=4

MEAN AND STANDARD DEVIATION BASED ON TRIPPLICATE ANALYSES OF ONE DIGESTED SAMPLE.

\*COLLECTED 6/1/75 (POST-DISPOSAL)

\*\*COLLECTED 5/3/75

\*\*\*SD BASED ON DUPLICATE DIGESTIONS OF ONE SAMPLE.

Table V-44  
Soluble Orthophosphate in Interstitial Water for Galveston  
Bay Entrance Channel Disposal Area Samples

Sampling Location	Date Collected (1975)	Soluble Ortho P (mg P/l)	
		X	SD
G.S. 2-III	7/14	0.83	0.003
G.S. 11	4/16	0.24	0
G.S. 15 (Ref)	7/14	0.26	0.002
G.S. 21	4/16	0.54	0.004
G.S. 23	4/17	0.26	0.005
G.S. 27 (Ref)	7/24	0.79	0
Buoy D*	8/26	0.08	0.008
Buoy D*	8/26	0.09	0.007
Buoy D*	8/26	0.54	0.003

Mean and standard deviation based on duplicate analyses.

\* Replicate grabs of sediment from one location.

Table V-45  
Soluble Orthophosphate in Ammonium Acetate-Extractable  
Fraction of Selected Sediments from the Galveston  
Bay Entrance Channel Disposal Area

Sampling Location	Date Collected (1975)	Soluble Ortho P (mg/kg)	
		X	SD
G.S. 2-III	7/14	0.24	0
G.S. 15 (Ref)	9/10	0.17	0
G.S. 27-II (Ref)	7/24	< 0.17	0
Buoy D*	8/26	< 0.17	0
Buoy D*	8/26	< 0.17	0
Buoy D*	8/26	< 0.17	0

Mean based on duplicate or triplicate analyses.

\* Replicate grabs of sediment from one location.

Table V-46  
Post-Disposal Soluble Orthophosphate Data: Galveston Bay  
Entrance Channel Disposal Site Interstitial  
Water Samples  
 October 10, 1975

Sampling Location	Soluble Ortho P (mg P/l)	
	$\bar{X}$	SD
Buoy B	6.9	0.28
Buoy C	2.0	0.04
Buoy C	4.2	0.08
Buoy D	2.5	0.02
G.S. 15 (Ref)	1.9	0.009
G.S. 27 (Ref)	1.6	0.3

Standard deviation calculated from duplicate analyses except for Buoy C values which were calculated from duplicate sediment samples.

Data are insufficient to determine if there is a relationship between IW soluble orthophosphate concentrations and ammonium acetate-extractable soluble ortho P, or between soluble ortho P concentrations in the interstitial water and the total phosphorus content of the sediment. Data are available for soluble ortho P in both IW and the ammonium extractable-fraction for only three samples. Of these, the sample with the highest IW concentration also had the greatest concentration in the ammonium acetate fraction. Corresponding data are available for IW soluble ortho P and total P in the sediment for Grid Squares 11, 21 and 23. It appears that as the soluble ortho P concentrations in the interstitial water from these grid squares increased, the total P in the sediment also increased. However, using the students' t-test comparing

the largest and smallest values, concentrations of total P in the sediment samples from G.S. 11, 21 and 23 were not statistically different at a 95 percent confidence level.

Table V-47 presents the mean total phosphorus concentrations found in the replicate grab samples and composites thereof from Buoy B<sub>1</sub> and Reference G.S. 15. At Buoy B<sub>1</sub> in the GBEC Disposal Site concentrations found ranged from 76 to 230 mg P/kg. The concentration found in the composited sample was well within this range and only 8 mg P/kg greater than the mean of all replicate samples. Utilizing standard one-way analysis of variance and Neuman-Kuels statistical testing procedures, it was found that at alpha = 0.005, 9 of the 10 samples had concentrations which were not statistically different from the rest at alpha = 0.001. It did appear that the first four samples collected had the highest concentrations (with the exception of the seventh). At alpha = 0.05 the first, second and fourth samples collected had a significantly higher concentration than the other samples. This likely resulted from the variation in shell content of the sediments collected at Buoy B<sub>1</sub>. On observation, the first samples had a considerable amount of shell in them; the later samples were mostly clay. The total P concentration found in Grid Square 9 (approximately where Buoy B<sub>1</sub> was located) in April, 1975, 141 mg P/kg, was within the range found in April, 1976. This would indicate that there was little effect from the successive dredged material disposal operations near Buoy B<sub>1</sub>.

The total P concentration at Reference Grid Square 15 (Table V-47) ranged from 322 to 542 mg P/kg for 11 replicate grabs. Again, the concentration of the composite samples was well within this range, and was 32 mg P/kg

Table V-47  
Concentrations of Total P in Replicate Grabs and  
Composites: Galveston Bay Entrance Channel  
Disposal Site - April, 1976

Buoy B <sub>1</sub> Replicate	Order Collected	Total P (mg P/kg)		Reference G.S. 15 Replicate	Order Collected	Total P (mg P/kg)	
		$\bar{X}$	SD			$\bar{X}$	SD
a	2	132	0	a	2	377	4
b	8	80	11	b	11	415	8
c	5	76	2	c	7	384	4
d	4	153	2	d	10	330	6
e	7	230	2	e	5	382	8
f	10	101	18	f	3	542	2
g	3	106	4	g	6	391	0
h	1	150	16	h	4	322	1
i	9	79	7	i	1	444	0
j	6	90	1	j	9	428	22
				k	8	414	18
Composite		129	40			368	4
Column		120	48			400	60

"Composite" indicates one sample composed of equal portions of replicate samples.

Mean and standard deviation of each replicate based on duplicate digestions of one sample.

Column mean and standard deviation are mean and standard deviation of the replicate grab mean concentrations.

less than the mean of the 11 replicate concentrations. Also within this range was the concentration found during the April, 1975, sampling of G.S. 15, indicating in this case that the sediment total P concentrations may not vary greatly. Using the same statistical testing procedures, at alpha = 0.001, there was only one sample, replicate f, which had a significantly different total P concentration from all the others. Statistically significant differences among the replicates occurred in five somewhat overlapping groups. For example, of replicates and composites in ranked order, 1, 2 and 3 were not different; 4 and 5 were not different; but 5 was different from 3; 4 through 9 were not different; and so forth.) In the order collected, 5, 6, 7, 8, 9 and 11 samples did not have statistically different concentrations (alpha = 0.001). The other samples' concentrations did not appear to be related to the order in which they were collected. The variation in sediment total P concentrations found both at Buoy B and G.S. 15 often did not appear to be related to the order in which the samples were taken. This observation tends to demonstrate the sampling variability found in successive grab samples collected off an anchored vessel.

#### Organic Carbon, Oil and Grease

#### Dredging Sites

Eleven sediment samples were collected from the dredging sites during the period April 12 to September 20, 1975. These included five samples from the GBEC between Buoys 1 and 11 and six samples from the TCCTB area. Table V-48 shows sampling locations, dates and analytical results.

Table V-48  
 Carbon and Oil and Grease Content of Dredging Site Sediments: Galveston  
Bay Entrance, Outer and Inner Bar Channels and Texas City Channel

Sampling Location	Date Collected	Percent Total Carbon		Percent Organic Carbon $\bar{X}$	Total Carbon SD	Oil and Grease (mg/kg)
		$\bar{X}$	SD			
Buoy 1	4/17	1.1	0.004	-	-	24
Buoy 1	6/11	1.3	0.06	0.96	0.05	-
Buoy 1	8/26	1.2	0.01	0.94	0.007	437
Buoy 7	4/12	2.8	0.05	0.03	0.004	-
Buoy 11	4/12	5.5	0.05	0.26	0.04	18
TCC 1	3/20	1.8	0.06	-	-	304
TCC 2	3/28	0.9	0.06	-	-	256
TCC 3	3/28	1.9	0.08	-	-	255
TCC 4	9/20	1.5	0.02	0.8	0.006	533
TCC 5	9/20	1.0	0.01	0.9	0.03	519
TCC 6	9/20	1.4	0.02	1.0	0.01	1335

Mean calculated from at least three determinations.

Dash (-) indicates no data available.

Results based on dry weight.

The data on sediments from the GBEC showed that the percent TC gradually increased from 1.1 at Buoy 1 to 5.5 at Buoy 11. The percent TOC followed a reverse trend. Buoy 1 sediment contained 0.94 percent TOC, and Buoy 11 sediment contained only 0.26 percent. These results may be correlated to the type of sediment at the different sites throughout the channel. Buoy 1 sediment is mostly clay and contains a higher percentage of organic carbon. Buoy 11 sediment is mostly sand and may contain a higher percentage of inorganic carbon from marine shells.

The oil and grease content in Buoys 1 and 11 sediments, collected on April 12 and 17, 1975, were 18 and 24 mg/kg, respectively. These results represented the hexane-extractable material from unacidified sediment. Sediment samples collected from Buoy 1 on August 26, 1975, contained 437 mg/kg oil and grease. This value represented the freon-extractable material on samples acidified to pH <2.

Data on sediments collected from the Texas City sites showed the percentage of TC ranging from 0.9 in TCC 2 to 1.9 in TCC 3 with an average of 1.4. Percent TC in Texas City Sites 1 and 4 sediments were comparable (1.8 and 1.5, respectively) despite the six-month lag between the sampling dates. Percent TOC on the three sediments collected from Texas City Sites 4, 5 and 6 were 0.8, 0.9 and 1.0, respectively. Concentrations of the oil and grease in the six sediments ranged from 255 mg/kg in TCC Site 3 to 1335 mg/kg in TCC Site 6 with an average of 534 mg/kg. The high concentration of oil and grease detected in TCC 6 was also associated with a high oxygen uptake value (1.17 mg/g). These results may indicate an industrial discharge of water containing oil and grease at this site. The data on dredging site sediments from the GBEC and the TCCTB seemed

to exhibit wide variability in terms of TC, TOC and oil and grease content.

#### Disposal Site

Pre-disposal. Fifty-nine sediment samples were collected from the disposal sites during the period from April 16 to September 10, 1975. All samples were analyzed for TC and TOC, and selected ones were analyzed for oil and grease. The first set of samples included 26 samples collected during the period from April 16 to May 3, 1975. Table V- 49 shows the sampling sites and results. Percent TC ranged from 0.5 in G.S. 8 to 1.3 in G.S. 14 with an average of 0.89. Percent TOC ranged from 0.3 in G.S. 14 to 1.1 in G.S. 27 with an average of 0.6. Oil and grease was determined on six sediments from G.S. Nos. 6, 9, 12, 15, 20 and 28. The concentrations of oil and grease ranged from 519 mg/kg in G.S. 20 to 991 mg/kg in G.S. 28. Variations of TC, TOC and oil and grease data from one grid to the other did not seem to follow a specific pattern. A statistical t-test showed that, at a 95 percent confidence level, the data on TC and TOC followed a normal distribution.

Eight sediment samples were collected from the reference site on the north side of the GBEC on May 13, 1975. All samples were analyzed for TC and TOC, but not oil and grease. Results are presented in Table V-50. Percent TC ranged from 0.6 in sampling location d to 0.8 in sampling locations e, g and h with an average of 0.7. Percent TOC ranged from 0.3 in sampling location g to 0.5 in sampling locations d and e. Variability of TC and TOC data from one location to the other was slight. It appeared that the reference site sediments were more uniform than the disposal site sediments. A statistical t-test on the data indicated no significant difference (at a 95 percent confidence level) between the mean and individual results of each sample.

Table V-49  
 Carbon and Oil and Grease Content of Galveston Bay Entrance  
Channel Disposal Site Sediments (Pre-disposal)

Sampling Location	Date Collected	Percent Total Carbon		Percent Organic Carbon $\bar{X}$	Total Carbon SD	Oil and Grease (mg/kg)
		$\bar{X}$	SD			
G.S. 2	4/17	0.8	0.06	0.6	0.04	-
G.S. 3	4/18	0.9	0.09	0.6	0.002	-
G.S. 4	4/16	0.9	0.03	0.6	0.03	-
G.S. 6	4/17	0.9	0.02	0.7	0.002	844
G.S. 7	4/16	0.8	0.02	0.6	0.06	-
G.S. 8	4/17	0.5	0.01	0.4	0.032	-
G.S. 9	4/17	0.7	0.07	0.5	0.1	644
G.S. 10	4/18	0.7	0.07	0.4	0.1	-
G.S. 11	4/16	1.0	0.1	0.6	0.1	-
G.S. 12	5/3	0.9	0.06	0.6	0.003	618
G.S. 13	4/17	0.8	0.03	0.5	0.005	-
G.S. 14	4/16	1.3	0.1	0.3	0.02	-
G.S. 15 (Ref) 4/17		0.8	0.02	0.6	0.02	681
G.S. 16	4/17	0.7	0.03	0.5	0.009	-
G.S. 17	4/29	0.8	0.03	0.4	0.04	-
G.S. 18	4/16	0.8	0.04	0.5	0.06	-

Table V-49 (Concluded)

Sampling Location	Date Collected	Percent Total Carbon		Percent Organic Carbon $\bar{X}$	Percent Total Carbon $\bar{X}$	Oil and Grease (mg/kg)
		$\bar{X}$	SD			
G.S. 19	5/3	0.9	0.04	0.7	0.003	-
G.S. 20	4/16	1.0	0.01	0.8	0.04	519
G.S. 21	4/17	-	-	-	-	-
G.S. 22	4/17	0.9	0.02	0.6	0.02	-
G.S. 23	4/17	0.8	0.02	0.6	0.01	-
G.S. 24	4/29	1.0	0.02	0.5	0.007	-
G.S. 25	4/21	1.0	0.1	0.8	0.02	-
G.S. 26	5/3	1.0	0.09	0.5	0.002	-
G.S. 27 (Ref)	4/16	1.2	0.1	1.1	0.08	-
G.S. 28	4/16	1.1	0.03	0.9	0.02	991

Mean calculated from at least three determinations.

Dash (-) indicates no data available.

Results based on dry weight.

Table V-50  
 Carbon Content of Reference Area Sediments, North Side  
Galveston Bay Entrance Channel, May 13, 1975

Reference Grid No.	Percent Total Carbon		Percent Total Organic Carbon	
	$\bar{X}$	SD	$\bar{X}$	SD
a	0.7	0.09	0.4	0.04
b	0.7	0.05	0.4	0.002
c	0.7	0.03	0.4	0.05
d	0.6	0.02	0.5	0.05
e	0.8	0.1	0.5	0.007
f	0.7	0.12	0.4	0.01
g	0.8	0.05	0.3	0.01
h	0.8	0.01	0.4	0.01

Mean calculated from at least three determinations.  
 Results based on dry weight.

Ten sediment samples were collected from G.S. 2 between May 6 and July 14, 1975. All samples were analyzed for TC and TOC. Results are presented in Table V-51. Percent TC in the four sediment samples collected on May 6 ranged from 0.5 in G.S. 2-IVa to 0.8 in G.S. 2-IIa with an average of 0.6. Percent TOC ranged from 0.2 in G.S. 2-Ia to 0.4 in G.S. 2-IIa with an average of 0.3. The three sediments collected on June 11, 1975, from G.S. 2-III contained TC ranging from 0.6 to 0.8 percent with an average of 0.75. Percent TOC ranged from 0.1 to 0.3 with an average of 0.23. The low TOC percent detected in the sample labeled 2-III post-disposal was also associated with low concentrations of organic nitrogen (157 mg/kg) and low sulfide (21 mg/kg). The three sediments collected from G.S. 2-III and 2-V on July 14, 1975, contained

Table V-51  
Carbon Content of Galveston Bay Entrance Channel  
Disposal Site Grid Square 2 Sediments

Sampling Location	Date Collected (1975)	Percent Total Carbon		Percent Total Organic Carbon	
		$\bar{X}$	SD	$\bar{X}$	SD
2-Ia	5/6	0.6	0.05	0.2	0.001
2-IIa	5/6	0.8	0.02	0.4	0.009
2-IVa	5/6	0.5	0.04	0.3	0.008
2-Va	5/6	0.6	0.02	0.3	0.004
2-III(post-disposal)	6/11	0.8	0.04	0.1	0.01
2-III	6/11	0.6	0.02	0.3	0.01
2-III	6/11	0.6	0.04	0.3	0.01
2-III	7/14	0.9	0.02	0.6	0.02
2-III	7/14	0.4	0.02	0.2	0.02
2-V	7/14	0.6	0.02	0.4	0.03

Mean calculated from at least three determinations.

Results based on dry weight.

TC ranging from 0.4 to 0.9 percent with an average of 0.63. The TOC for these samples ranged from 0.2 to 0.6 with an average of 0.3.

Fifteen sediment samples were collected during the period from July 21 to September 10, 1975, from G.S. Nos. 12, 14, 15, 27 and Buoys C and D. Results are presented in Table V-52. Percent TC and TOC in the sediment from G.S. 12-I were 0.8 and 0.2, respectively. These values are less than the 0.9 and 0.6 percent previously detected on sediment collected from G.S. 12 on May 13. The two sediment samples collected from G.S. Nos 14-I and 14-V contained 0.7

Table V-52  
 Pre-Disposal Carbon and Oil & Grease Content of Galveston Bay  
 Entrance Channel Disposal Site Sediments

Sampling Location	Date Collected (1975)	Percent Total Carbon		Percent Organic Carbon <u>X</u>	Percent Total Organic Carbon <u>X</u>	Oil and Grease (mg/kg) SD
		<u>X</u>	SD			
G.S. 12-I	7/21	0.8	0.1	0.2	0.009	56.9
G.S. 14-I	7/22	0.7	0.03	0.3	0.01	-
G.S. 14-V	7/22	1.0	0.04	0.8	0.02	-
G.S. 15-I (Ref)	7/23	0.7	0.05	0.4	0.01	-
G.S. 27-I (Ref)	7/24	1.1	0.02	0.7	0.02	-
G.F. 27 (Ref)	7/24	1.0	0.02	0.7	0.02	-
Buoy C	8/26	0.8	0.1	0.6	0.02	-
Buoy C	8/26	0.8	0.09	0.4	0.02	51.3
Buoy C-II	9/10	0.7	0.007	0.5	0.004	53.9
Buoy C-II	9/10	0.8	0.003	0.4	0.01	-
Buoy C-III	9/10	1.0	0.06	0.5	0.01	-
Buoy C-IV	9/10	0.8	0.03	0.5	0.04	-
Buoy D	8/26	0.8	0.04	0.5	0.04	69.7
Buoy D	8/26	0.7	0.007	0.5	0.04	-
Buoy D	8/26	0.6	0.05	0.4	0.04	-

Mean calculated from at least three determinations.  
 Dash (-) indicates no data available.

Results based on dry weight.

and 1.0 percent TC, respectively. The TOC percent of the same samples were 0.3 and 0.8, respectively. Sediment samples previously collected from the same grid on April 16 had 1.6 percent TC and 0.3 percent TOC. Sediment samples from G.S. 15-I contained 0.7 percent TC and 0.4 percent TOC. Previous values of TC and TOC in sediment from the same site were 0.8 and 0.6, respectively. The two sediment samples collected from G.S. 27-I contained comparable percentages of TC (1.1 and 1.0 respectively) and the same percentage of TOC (both 0.7).

Table V-52 also shows data on six sediment samples collected from Buoy C. Two of these were collected on August 26 and four were collected on September 10, 1975. The first two sediments both contained 0.8 percent TC. Percent TOC in one sample was 0.6, and in the other, 0.4. The other four sediments contained TC ranging from 0.7 to 1.0 percent with an average of 0.7. The TOC of the same samples ranged from 0.4 to 0.5 percent with an average of 0.5. These values are comparable to the 0.8 TC percent and the 0.5 TOC percent previously detected in G.S. 13 on April 17, 1975. Two of the six sediments from Buoy C were analyzed for oil and grease and both contained comparable concentrations (513 and 539 mg/kg). The three sediment samples collected from Buoy D on August 26 contained percent TC ranging from 0.6 to 0.8 with an average of 0.7. Percent TOC for the same samples ranged from 0.4 to 0.5 with an average of 0.47 percent. One of the Buoy D sediments was analyzed for oil and grease and was found to contain 697 mg/kg.

In summary, analysis of the disposal site sediments, pre-disposal, presented baseline characteristics of the sediments in terms of TC, TOC and oil and grease. Though samples were collected over a period of six months,

the data seemed to be consistent. Except for a few instances, no significant changes were observed in the sediment characteristics during this period.

Post-disposal. Sixty-eight post-disposal sediment samples were collected from different grids at the disposal sites during the period from September 10, 1975, to April 21, 1976. All samples were analyzed for TC and TOC and selected ones were analyzed for oil and grease. Samples analyzed for oil and grease were selected arbitrarily. The first set of samples included ten sediments collected on September 10, 1975, from Buoy D and G.S. 15. Five sediment samples were collected from each site. Results are presented in Table V-53. Percent TC in Buoy D ranged from 0.6 to 0.8 with an average of 0.7. Percent TOC ranged from 0.4 to 0.5 with an average of 0.44. Sediment samples collected previously from Buoy D on August 26, pre-disposal, contained comparable percentages of TC and TOC (0.7 and 0.44). The five sediment samples collected from G.S. 15 contained TC ranging from 0.4 to 1.0 percent with an average of 0.8. Percent TOC ranged from 0.2 to 0.7 with an average of 0.52. Also, these values are comparable to the 0.7 percent TC and the 0.4 percent TOC previously detected in G.S. 15 sediment, pre-disposal (Table V-52). Except for the sample labeled G.S. 15-II which contained 0.4 percent TC and 0.2 percent TOC, variability of TC and TOC within Buoy D and G.S. 15 was slight. One of the G.S. 15 sediments (15-V) was analyzed for oil and grease and found to contain 516 mg/kg.

Twelve sediment samples were collected on October 10, 1975, from different disposal locations. These included three sediments from Buoy B, two from both Buoy C and G.S. 15, four from Buoy D and one from G.S. 27. Data on TC and TOC analyses are presented in Table V-54. The three Buoy B

**Post-Disposal Carbon and Oil and Grease Content of Galveston Bay Entrance**  
**Channel Disposal Site Sediments**  
**(September 10, 1975)**

Sampling Location	Percent Total Carbon		Percent Total Organic Carbon		Oil & Grease (mg/kg)
	$\bar{X}$	SD	$\bar{X}$	SD	
Buoy D-1	0.6	0.03	0.4	0.005	-
Buoy D-2	0.7	0.02	0.5	0.01	-
Buoy D-3	0.8	0.03	0.5	0.01	-
Buoy D-4	0.6	0.02	0.4	0.005	-
Buoy D-5	0.7	0.01	0.4	0.01	-
G.S. 15-I (Ref)	0.7	0.01	0.5	0.009	-
15-II (Ref)	0.4	0.02	0.2	0.002	-
15-III (Ref)	1.0	0.02	0.7	0.01	-
15-IV (Ref)	1.0	0.01	0.6	0.02	-
15-V (Ref)	1.0	0.01	0.6	0.01	516

Mean calculated from at least three determinations.

Dash (-) indicates no data available.

Results based on dry weight.

Table V-54  
Carbon Content of Galveston Bay Entrance Channel  
Disposal Site Sediments (Post-Disposal)  
 October 10, 1975

Sampling Location	Percent Total Carbon		Percent Total Organic Carbon	
	$\bar{X}$	SD	$\bar{X}$	SD
Buoy B Ref <sub>2</sub>	1.3	0.08	0.2	0.02
Buoy B Mound <sub>1</sub>	0.6	0.001	0.3	0.02
Buoy B Mound <sub>2</sub>	1.1	0.07	0.2	0.005
Buoy C Ref <sub>2</sub>	0.9	0.02	0.6	0.02
Buoy C Mound <sub>2</sub>	4.6	0.26	0.03	0.002
Buoy D Ref <sub>1</sub>	0.7	0.04	0.4	0.009
Buoy D Ref <sub>2</sub>	0.7	0.01	0.4	0.007
Buoy D Mound <sub>1</sub>	2.7	0.11	0.2	0.009
Buoy D Mound <sub>2</sub>	2.4	0.14	0.1	0.006
G.S. 15-III (Ref)	0.6	0.02	0.4	0.01
G.S. 15-III (Ref)	0.9	0.05	0.6	0.02
G.S. 27-III (Ref)	0.8	0.01	0.5	0.005

Mean and standard deviation calculated from at least three determinations.

Results based on dry weight.

sediments contained TC ranging from 0.6 to 1.3 with an average of one percent. Percent TOC ranged from 0.2 to 0.3 with an average of 0.23. Sediment sampling collected from G.S. 9 on April 17, 1975, pre-disposal, had 0.7 percent TC and 0.5 percent TOC.

From the Buoy C sediment samples the one designated Buoy C Mound<sub>2</sub> had an extremely high TC percentage (4.6) and an extremely low TOC percentage (0.03). This sample also had very low organic nitrogen and sulfide concentrations, 131 mg/kg and 10 mg/kg, respectively. The other Buoy C sediment (Reference 2) contained 0.9 percent TC and 0.6 percent TOC which were comparable to the values previously found in Buoy C sediment, pre-disposal (Table V-52).

The four Buoy D sediment samples had two levels of TC and TOC values. The two samples designated Buoy D, References 1 and 2 both contained 0.7 percent TC and 0.4 percent TOC. The other two samples designated Buoy D Mounds 1 and 2 contained 2.7 and 2.4 percent TC. Percent TOC in the same samples were 0.2 and 0.1, respectively. The latter TOC values are considerably lower than values previously found in Buoy D sediment, pre-disposal (Table V-52). These results may indicate a disposal of a sandy type of sediment containing marine shells.

The two sediment samples collected from G.S. 15 contained 0.6 and 0.9 percent TC. Percent TOC was 0.4 and 0.6, respectively. These values are comparable to the values previously found in G.S. 15 sediment (Table V-52). The G.S. 27 sediment sample contained 0.8 percent TC and 0.5 percent TOC. Sediment samples collected from G.S. 27 on July 24, 1975, pre-disposal, contained 1.0 percent TC and 0.7 percent TOC.

Twenty-five post-disposal sediment samples were collected December 4, 1975. These included five samples from each of the following sites: Buoys B, C, D, G.S. 15 and G.S. 27. All sediments were analyzed for TC and TOC but not oil and grease. Data are presented in Table V-55. Percent TC in Buoy B sediments ranged from 0.7 to 2.9 with an average of 1.2. Percent TOC ranged from 0.3 to 1.1 with an average of 0.62. The five Buoy C sediments contained TC ranging from 0.8 to 1.9 percent with an average of 1.1. Percent TOC ranged from 0.4 to 1.7 with an average of 0.8. Buoy D sediment samples contained TC ranging from 0.7 to 1.8 with an average of 1.1. The TOC values ranged from 0.5 to 0.7 percent with an average of 0.6. Percent TC in G.S. 15 sediments ranged from 0.4 to 1.0 with an average of 0.8. Percent TOC ranged from 0.1 to 0.6 with an average of 0.5. G.S. 27 sediments contained TC ranging from 0.8 to 1.0 percent with an average of 0.9. The TOC ranged from 0.6 to 0.8 with an average of 0.7.

Twenty-one sediment samples were collected on April 21, 1976, from Buoy B and G.S. 15. Using the same sampling technique, ten sediments were collected from the same site at Buoy B and eleven were collected from G.S. 15. All 21 sediments were individually analyzed for TC, TOC and oil and grease. The samples from each site were later composited and analyzed in replicates for each parameter.

Results on Buoy B sediments are presented in Table V-56. The ten Buoy B sediments contained TC ranging from 0.4 to 4.7 percent with an average of 1.3. The five replicates of the composite sediments contained TC ranging from 0.9 to 1.2 percent with an average of 1.0. Percent TOC in the ten Buoy B sediments ranged from 0.1 to 2.6 with an average of 0.8. The five replicates of the composite sediment

Table V-55  
Carbon Content of Galveston Bay Entrance Channel  
Disposal Site Sediments, December 4, 1975 (Post-Disposal)

Sampling Location	Percent Total Carbon		Percent Total Organic Carbon	
	$\bar{X}$	SD	$\bar{X}$	SD
Buoy B 2-I	2.9	0.24	1.1	0.04
Buoy B 2-II	0.7	0.06	0.3	0.01
Buoy B 2-III	0.9	0.01	0.7	0.02
Buoy B 2-IV	0.8	0.04	0.5	0.008
Buoy B 2-V	0.8	0.02	0.5	0.016
Buoy C 12-I	0.9	0.03	0.6	0.02
Buoy C 12-II	1.1	0.18	0.5	0.01
Buoy C 12-III	1.9	0.26	1.7	0.07
Buoy C 12-IV	0.8	0.01	0.4	0.007
Buoy C 12-V	1.0	0.02	0.7	0.009
Buoy D 14-I	1.8	0.008	0.7	0.01
Buoy D 14-II	1.1	0.1	0.6	0.05
Buoy D 14-III	1.1	0.04	0.7	0.01
Buoy D 14-IV	0.9	0.009	0.6	0.04
Buoy D 14-V	0.7	0.007	0.5	0.01
G.S. 15-I (Ref)	0.8	0.008	0.5	0.025
G.S. 15-II (Ref)	0.9	0.021	0.6	0.047
G.S. 15-III (Ref)	0.4	0.035	0.1	0.01
G.S. 15-IV (Ref)	0.7	0.023	0.5	0.007
G.S. 15-V (Ref)	1.0	0.015	0.6	0.028
G.S. 27-I (Ref)	0.9	0.03	0.7	0.02
G.S. 27-II (Ref)	0.8	0.004	0.6	0.02
G.S. 27-III (Ref)	1.0	0.006	0.8	0.01
G.S. 27-IV (Ref)	0.9	0.013	0.8	0.008
G.S. 27-V (Ref)	0.9	0.017	0.7	0.006

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Mean calculated from at least three determinations.

Results based on dry weight.

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AQUATIC DISPOSAL FIELD INVESTIGATIONS, GALVESTON, TEXAS, OFFSHO--ETC(U)  
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Table V-56  
Carbon and Oil and Grease Content of Buoy B Sediments,  
April, 1976 (Post-Disposal)

Sample Number	Percent Total Carbon		Percent Total Organic Carbon		Oil and Grease	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
1	1.0	0.15	0.5	0.11	113	
2	1.1	0.16	0.9	0.08	114	
3	0.9	0.05	0.6	0.03	108	
4	1.4	0.06	1.1	0.17	140	
5	1.3	0.08	1.0	0.19	287	
6	4.7	0.26	2.6	0.29	143	
7	0.8	0.16	0.3	0.02	147	
8	0.4	0.03	0.1	0.01	112	
9	1.1	0.04	0.8	0.1	98	
10	0.5	0.03	0.1	0.03	150	
Average	1.3	1.22	0.8	0.73	141	54.5
Composite						
Replicate-1	0.9	0.05	0.8	0.13	107	
Replicate-2	0.9	0.01	0.9	0.11	63	
Replicate-3	1.1	0.28	0.8	0.06	95	
Replicate-4	0.9	0.08	1.1	0.17	-	
Replicate-5	1.2	0.11	0.9	0.22	-	
Average	1.0	0.17	0.9	0.10	88	22.7

Mean calculated from at least three determinations.

Dash (-) indicates no analysis was run.

Results based on dry weight.

contained TOC ranging from 0.8 to 1.1 with an average of 0.9. Individual analyses of oil and grease in Buoy B sediment showed values ranging from 98 to 287 mg/kg with an average of 141 mg/kg. Triplicate analysis of the composite sediment showed 107, 63 and 95 mg/kg, respectively.

Results on G.S. 15 sediments are presented in Table V-57. The eleven G.S. 15 sediments contained TC

Table V- 57  
Carbon and Oil and Grease Content of G.S. 15 Sediments,  
April, 1976 (Post-Disposal)

Sample Number	Percent Total Carbon		Percent Total Organic Carbon		Oil and Grease	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
1	0.9	0.18	0.6	0.01	279	
2	0.9	0.08	0.7	0.03	271	
3	1.0	0.06	0.7	0.01	284	
4	1.0	0.01	0.5	0.01	193	
5	0.9	0.08	0.5	0.02	278	
6	0.9	0.04	0.6	0.01	258	
7	0.9	0.08	0.7	0.01	204	
8	0.9	0.03	0.7	0.02	284	
9	0.9	0.08	0.5	0.00	238	
10	0.9	0.06	0.6	0.00	207	
11	0.8	0.01	0.6	0.01	281	
Average	0.9	0.05	0.6	0.08	252	35.6
Composite						
Replicate-1	0.9	0.02	0.7	0.03	100	
Replicate-2	0.9	0.01	0.6	0.02	216	
Replicate-3	0.9	0.01	0.6	0.01	86	
Replicate-4	0.8	0.01	0.6	0.02	88	
Replicate-5	0.9	0.01	0.7	0.04	117	
Average	0.9	0.02	0.6	0.05	121	54.3

Mean calculated from at least three determinations.

Results based on dry weight.

ranging from 0.8 to 1.0 with an average of 0.9 percent. The five replicates of G.S. 15 composite had TC from 0.8 to 0.9 with an average of 0.9. Individual TOC percentages in G.S. 15 sediments ranged from 0.5 to 0.7 with an average of 0.6. Percent TOC in the five replicates of the composite ranged from 0.6 to 0.7 with an average of 0.6. Oil and grease concentrations in the eleven G.S. 15 sediments ranged from 193 to 284 mg/kg with an average of 252 mg/kg. Triplicate analysis of composite sediment showed values ranging from 86 to 216 mg/kg with an average of 121 mg/kg.

Sampling and analysis of the sediments collected on April 21, 1976, were designed to investigate the variability of the sediment characteristics within the same site. The data presented in Tables V-56 and V-57 show that Buoy B sediment is more heterogeneous than G.S. 15 sediment with respect to TC, TOC, and oil and grease. Based on the available information, Buoy B site was subject to successive disposal operations from Galveston Bay Entrance Channel. The data also showed significant differences in the oil and grease concentrations found in individual samples from either Buoy B or G.S. 15 and those found in the replicates from the composite sediments. This could be explained by the fact that the samples were stored just above freezing for about four months before compositing them. Decomposition of some degradable organics may account for the low oil and grease concentrations found in the composite sediment. In both Buoy B and G.S. 15 average percent TOC of individual samples was not significantly different (at a 95 percent confidence level) from values found in replicates of the composite samples.

## PART VI: DISCUSSION

### Introduction

This part reviews and discusses the results obtained in this study which were reported in previous chapters. It focuses on generalized data trends and specifically examines the significance of these data as they relate to the chemical characteristics of the sediments in the GBEC Disposal Site and to the environmental impact of dredged material disposal on the disposal site water column. In this discussion, the term "significant" is, unless otherwise noted, used in an ecological sense. It is based on examination of the data obtained in this study and the experience of the authors in evaluating the physical and chemical effects of contaminants on aquatic organisms and water quality.

### Overall Approach for Assessment of Environmental Impact

#### Water Column

In interpreting data of the type obtained in this study on the release of contaminants to the water column as a result of dredged material disposal, it is important to consider the time-concentration of contaminant relationships that existed for aquatic organisms in the turbid plume. There are basically three situations which must be considered. The worst case situation is one in which a planktonic or nektonic organism moves with or stays within the turbid plume until it has been dispersed. A second case involves nektonic organisms which may swim through the turbid plume and thereby receive a short-term exposure. The third case is one in which the nektonic organisms avoid the turbid plume and therefore receive no exposure.

In evaluating the worst case situation (i.e., movement with the turbid plume), consideration must be given to

the critical concentration of contaminants for aquatic life. In July, 1976, the US EPA<sup>11</sup> released their Quality Criteria for Water in which they provide an assessment of the critical concentrations for many chemicals for various forms of both marine and freshwater aquatic life. This publication is based on an update of the information provided in Water Quality Criteria, 1972 prepared by NAS-NAE, 1973.<sup>33</sup> While the 1976 criteria do not cover all possible contaminants and all possible aquatic organisms, they do provide a sufficient body of knowledge to be useful in making a reasonable assessment of the potential ecological impact of chemical contaminants on water quality. Based on the aquatic toxicology studies that have been conducted thus far, it is improbable that a new chemical would show toxicities to aquatic life significantly different from the toxicities reported in the US EPA Quality Criteria for Water.<sup>11</sup> Further, it is improbable that any untested organism would show sensitivity to a contaminant much greater than that reported in the US EPA Quality Criteria for Water.

In utilizing the numerical values presented in the US EPA Quality Criteria for Water, consideration must be given to the fact that in general these values are based on chronic exposure situations where the organism is exposed to the available form of the contaminant throughout its lifetime or a significant part thereof. As discussed below, the duration of the turbid plume associated with the Galveston dumps is such that it would be virtually impossible for any water column organism to encounter a chronic exposure situation at the GBEC Disposal Site. Therefore, the numerical values developed by the US EPA in their Quality Criteria for Water are not applicable to the dredged material disposal operations such as encountered in GBEC

disposal area because the potential time of exposure for water column organisms is considerably less than the time necessary for these aquatic organisms to obtain an excessive chronic exposure.

Further, the US EPA Quality Criteria for Water numerical values should not be used to judge the significance of chemical contaminants of dredged material disposal associated with GBEC disposal studies because the EPA criteria are based on total contaminant concentrations. A majority of the contaminants present in dredged sediments have been found to be in an unavailable form which will not have an adverse effect on aquatic life and water quality.<sup>1,2,3,6</sup> Further discussion on the appropriate use of US EPA Quality Criteria for Water may be found in Lee<sup>42</sup> and Lee et al.<sup>43</sup>

In the worst case situation described previously for water column organisms and, to a lesser extent, benthic or epibenthic organisms residing near but outside of the immediate dump area, the contaminant concentration-time relationship that exists within the plume must be compared to the critical available concentration-time relationship for adverse effects on aquatic organisms at or near the disposal site. The characteristics of most open-water disposal operations including those monitored at the Galveston Bay Entrance Channel Disposal Site are such that much greater concentrations of contaminants can be released to the water column without having an adverse effect on water quality and aquatic organisms than would be permitted by the US EPA Quality Criteria for Water released in July, 1976. A case-by-case evaluation should be made for each disposal site to ensure that the expected general situation of lack of significant effects is borne out at a particular site.

### Sediments

In determining the potential long-term significance of chemical contaminants present in dredged sediments to benthic or epibenthic organisms at the disposal site and to planktonic and nektonic organisms in the overlying waters, consideration must be given to several factors. First, for the water column organisms, the question must be asked whether the disposal of the dredged sediments results in a long-term release of contaminants to the overlying waters which has a significant adverse effect on water column organisms. In general, it is suspected that it is unlikely that the rate of release of contaminants from deposited sediments would be sufficient in most open-water disposal systems to result in excessive concentrations of contaminants in the overlying waters. There is very little evidence for this kind of problem in the water pollution field and, in fact, except for mercury near the point where large amounts have been deposited in sediments from industrial waste discharges, few other contaminants present in sediments have been demonstrated to cause excessive concentrations in overlying waters. Even where excessive concentrations occur, these are usually close to the source of contamination, and it is difficult to ascertain whether the contamination comes from the sediments or from the direct discharge.

The second area of concern with respect to sediments is that of the direct uptake of the contaminants from sediments by benthic and epibenthic organisms. In order to determine whether this is a problem at a particular disposal site, samples of the organism should be collected and the concentrations of contaminants found within them compared to critical body burdens for the organisms and for their use as sources of food for higher organisms. It is important to emphasize that the concern should not focus just on increased uptake of contaminants. The increase in concentration within

the organism in order to be detrimental must exceed the critical concentration for that organism or higher organisms.

In attempting to ascertain the significance of chemical contaminants in sediments, it is important to sort out the physical effects related to grain size and the physical-chemical effects related to organic content. Both grain size and organic content of sediments have been shown to be dominant factors in influencing the numbers and types of benthic organisms present in sediments. When the U. S. Army Corps of Engineers and the US EPA designate a dredged material disposal area, it is generally recognized that disposal in this region may alter the numbers and types of organisms present in the sediment. The physical effects of disposal would be of primary concern. It is likely that even disposal of sand on sand with exactly the same chemical composition without any significant increase in concentrations of available forms of contaminants would alter the numbers and types of organisms present at a disposal site. Certainly, disposal of different grain size and different organic content materials should result in a change in the numbers and types of organisms at the disposal site.

The issue should not be whether there is an altered number of organisms at the disposal site, but whether outside of the designated disposal area the numbers and types of organisms are significantly altered because of disposal operations. Further, with respect to this study and the current dredged material disposal criteria that is being used to determine methods of disposal, focus must be placed on the concentrations of available forms of contaminants present in dredged sediments which may have a significant adverse effect on the numbers and types of benthic organisms in areas adjacent to the designated disposal area. This point has been discussed by Mariani et al.<sup>44</sup> and Lee et al.<sup>45</sup>

### Review and Evaluation of Specific Parameters

Evaluation of the significance of chemical contaminants in the dredged sediments on the disposal site water column and sediments of the area draws heavily from the companion study that was conducted at the same time. This study was devoted to evaluating the reliability of the elutriate test as a means of determining the release of contaminants from dredged sediments. The details of this study are being reported by Lee et al.<sup>1</sup>. Only a summary of the results is presented here.

#### Optical Properties

The optical properties of the water column at the disposal sites are of interest from two points of view. First, turbid water is aesthetically displeasing. In areas where background turbidity is relatively low, dredged material disposal which creates highly turbid water persisting for a long period of time could represent a significant degradation of water quality. The turbidity arising from disposal of dredged sediments by either open-water dumping or onland disposal with overflow entering nearby watercourses could adversely affect water quality by decreasing light penetration and increasing suspended solids. Decreased light penetration is of concern because it could reduce the primary productivity of the disposal area waters. Increased suspended solids could be detrimental to water column organisms. Similarly, settled sediment could possibly have adverse effects on benthic and epibenthic organisms.

A second reason for interest in the turbidity arising from dredged material disposal is that it serves as a short-term tracer of the fate of any soluble chemical contaminants released by disposal of dredged sediments. The settling rate and concentrations of the suspended sediments in the turbid plume that moves away from the disposal site

are such that the turbidity can be considered a short-term conservative tracer. Thus, the plume can be used to locate potentially high concentrations of soluble contaminants released by the dumping operation.

The use of transmissometers in this study proved to be an efficient method of monitoring the location and extent of the turbid plume. By positioning the sampling boat downcurrent from the disposal site, the transmissometer made it possible to monitor the passage of the turbid plume at any depth within the water column. This approach enabled the development of a more efficient sampling program than would have been possible otherwise.

The optical properties of the GBEC Disposal Site water column prior to disposal were highly variable, being dependent on the relative proportions of the comparatively clear open waters of the Gulf of Mexico and highly turbid GBEC waters and nearshore Gulf waters. The turbidity of the nearshore Gulf waters and GBEC waters was dependent on weather conditions, as wind-induced mixing and turbulence can cause the suspension of shallow water sediments. The relative proportions of these three water types were dependent on the currents controlled by tides, the general circulation patterns of the Gulf and the winds.

The clarity of the disposal site water was generally greater than that of the GBEC. As demonstrated by aerial photographs made by Bouma et al.,<sup>27</sup> there appeared to be a well-defined plume of turbid water that originated in Galveston Bay and moved in a south-southwest direction into the open waters of the Gulf. At the GBEC Disposal Site, surface waters tended to be less turbid than mid- or bottom waters. The turbidity associated with the waters adjacent to the bottom often reflects the seasonally strong bottom currents in the nearshore waters of the Gulf in the Galveston region. These currents are able to suspend fine

sediments to create a naturally turbid layer of water adjacent to the bottom.

The data collected during disposal indicate that a well-defined distribution pattern of suspended material within the water column occurs immediately after the disposal of dredged sediments. In general, the surface and mid-depth plumes were short-lived, lasting 2 to 15 minutes at any one location near the disposal site. The bottom plumes were usually more turbid than either the surface or mid-depth plume and lasted from 10 minutes to well over one hour at a location near the disposal site. The intensity and duration of the plumes appear to be governed by the type of sediment, the prevailing currents and the weather conditions at the time of disposal.

Pre-disposal Secchi depths were on the order of 1 to 3 meters. During passage of the turbid plume, the Secchi depth decreased to a few tenths of a meter. By using a transmissometer with a 10-cm light path, it was found that the water decreased from pre-disposal values of 50 to 90 percent light transmission to essentially zero during some disposal operations. The lowest percent transmission occurred in waters adjacent to the bottom.

Percent transmission data and visual observations from the sampling ship indicated that the turbid surface plume passed the sampling ship in one to two minutes. Generally, the plume near bottom lagged behind the surface plume by a minute or so and persisted for longer periods of time. The time lapse was due to the fact that current velocities were generally higher at the surface (1 to 1.5 knots) than near the bottom (0.5 knots). Occasionally, the bottom plume persisted from one dump to the next without a discernible increase in light transmission between dumps. The persistence of the bottom plume may have been caused by bottom currents, which dislodged previously deposited sediments,

thereby creating a turbid plume which traveled along the bottom. Surveys conducted some 12 hours after cessation of dumping indicated that this type of phenomenon was relatively short-lived.

The post-disposal data on the optical properties of the water column show that the disposal operations in late August and September, 1975, had no long-lasting effect on the clarity of the water column. The magnitude of the background turbidity measured on September 10 by Bouma et al.<sup>27</sup> was such that the disposal of dredged sediments did not significantly change water quality related to particulate matter present in the water column. On overflights during the study period, Bouma et al.<sup>27</sup> observed that the turbid surface plume generally persisted for one hour or less. They found that turbidity from other sources, such as the discharge from Galveston Bay, was at least equal to and often more intense than turbidity arising from the disposal operations. Therefore, the changes in optical properties resulting from disposal operations would generally be judged to have little or no effect on the overall aesthetic quality of the water. Furthermore, the decreased light penetration associated with the turbidity created by dumping operations would not be expected to significantly affect the primary productivity in the disposal area.

The US EPA Quality Criteria for Water<sup>11</sup> established a criteria for freshwater fish and other aquatic life for settleable and suspended solids and turbidity where the concentrations of these materials should not reduce the depth of the compensation point for photosynthetic activity by more than 10 percent from the seasonally established norm. The compensation point is the point at which photosynthesis equals respiration in a water column. Examination of the optical properties of the water column data obtained in this

study shows that based on Secchi depth data, the compensation point would be decreased by more than 10 percent in the turbid plume. The overall extent and duration of the turbid plume based on aerial photography is such that the GBEC disposal operations would probably not be in violation of the US EPA Quality Criteria for Water for suspended solids and turbidity because of the intermittent nature of the dumping operations and the short duration of the turbid water following dumping.

It should be noted that while the emphasis in this part of the study was on the significance of chemical contaminants associated with a dredged sediment, it is important to also consider whether the suspended solids released during the disposal operation could be adverse to aquatic organisms in the disposal site water column. Peddicord *et al.*<sup>46</sup> have done extensive studies on this question and have found results similar to those reported by Lee and Plumb<sup>2</sup> in their literature review on this topic. They reported that, in general, aquatic organisms are insensitive to large concentrations of suspended solids. Many aquatic organisms are adversely affected only by concentrations in the grams per liter range and greater, and only when these levels persist from several days to several weeks.

Compared to the amounts of suspended solids normally transported during storms, the amounts transported by dumping of sediments in the turbid plume to adjacent areas would be insignificant as far as having any physical effect (e.g., burial) on benthic and epibenthic organisms. From an overall point of view, the turbidity associated with the disposal operations is judged to have an insignificant effect on disposal area water quality.

### Oxygen Demand and Dissolved Oxygen Depletion

Since dredged sediments often have appreciable oxygen demand, there is legitimate concern over whether or not disposal of dredged sediment could deteriorate water quality at the disposal site. Pre-disposal studies showed that generally D.O. in the disposal area was at or near D.O. saturation concentrations. However, profiles taken in the GBEC on June 11, 1976, showed appreciable D.O. depletion in the bottom waters. This decrease in D.O. was mostly due to oxygen demand of the sediments.

Results obtained from the water column measurements during the disposal operations were compared to the results of the oxygen demand tests for the appropriate sediments. As discussed earlier, all but four of the disposal operations monitored produced a D.O. decrease in the disposal area water column (three showed no change and one, an increase), as is seen in Table VI-1. These decreases were expected because of the data obtained from the oxygen demand test reported in Part V.

The D.O. concentrations were expected to decrease more than observed during disposal of the TCCTB sediment. As Table V-3 shows, these had a significantly higher oxygen demand than the other dredged sediments tested. However, the decrease in the oxygen content in the water column observed during the disposal of TCCTB sediments was similar to the decrease noted during Galveston Dumps Nos. 4 and 5 when material from Buoys 1-3 was disposed.

A factor which could influence the oxygen demand of the Texas City sediments was the travel time between dredging and disposal sites. The longer the material stays in the dredge hopper, the greater the possibility for

Table VI-1  
Oxygen Depletion During the Monitored Dumps

Dump Nos.	Dredging Location, Channel Buoy Nos.	Depth of Measured Change (m)	Dissolved Oxygen Change in the Turbid Plume (mg/l)
<b>GBEC</b>			
1	6 through 8	all	0.0
2	6 through 8	12	+0.3
3	6 through 8	15	-1.0
4	1 through 3	14	-1.7
5	1 through 3	14	-1.6
6	3 through 7	15	-0.5
7	3 through 7A	14	0.0
<b>TCC</b>			
1	Texas City Channel Turn- ing Basin	none	0.0
2	Texas City Channel Turn- ing Basin	all	-1.5

oxidation due to mixing in the hopper. This would reduce the oxygen demand exerted on the receiving water. The distance from the TCCTB to the disposal area is approximately 12 km, while the distance from Buoy 1 to the disposal area is approximately 2 km.

The volume of dredged material would also affect the depletion of D.O. at the disposal site. Higher sediment-to-water ratios had more material available to exert a demand on the water column. The volume of sediment dredged from the Texas City site per load was considerably smaller than that typically taken from the GBEC. Both the longer

travel time and the smaller volume of sediments may have contributed significantly to the lower D.O. depletion observed during the Texas City dumps.

The sulfide concentration of all but one Texas City Channel sediment sample (TCC No. 5) was higher than that of the Buoy 1 sediment. Texas City Channel sediment generally had a sulfide content of approximately 1,000 mg/kg on a dry weight basis, while the GBEC Buoy 1 sediment had 250 mg/kg sulfide content. It was noted that in most cases, an increase in sulfide concentration was related to an increase in oxygen uptake. This was expected because one of the sources of oxygen demand in sediments is sulfide. Sulfide and ferrous iron oxidize readily upon contact with dissolved oxygen under the normal dredging and disposal conditions found in this study. It is interesting to note that Buoy 1 sediments had greater total iron content than did Texas City Channel sediments. Since the Buoy 1 sediments had a lower overall oxygen demand, it is likely that a significant part of the Buoy 1 sediment iron is in an oxidized form.

A decrease in the dissolved oxygen levels was noted at some point in most of the operations monitored (see Table VI-1). The greatest depletion (1.7 mg/l) was observed in Galveston Dump No. 4 at a depth of 14 meters. It should be noted that at no time during these GBEC studies did the dissolved oxygen concentration fall below the 5.0 mg/l lower limit proposed by the US EPA.<sup>11</sup> This level of dissolved oxygen is considered to be the minimum concentration required by many aquatic organisms. In Texas City Dump No. 2 a minimum D.O. of slightly over 4 mg/l was found during

passage of the turbid plume at the monitoring ship. Because of the short duration of this depressed D.O., it would not have a significant adverse effect on water column organisms at any single location or for those organisms that moved with the turbid plume. In most cases the dissolved oxygen concentrations returned to the pre-disposal levels at the monitoring site within ten minutes of passage of the turbid plume. During Galveston Dump Nos. 5 and 6 and Texas City Dump No. 2, near the bottom, D.O. decreased by less than 1 mg/l for approximately one hour after disposal. This depletion corresponded to a reduction in percent light transmission. A probable explanation for this phenomenon is that the dredged material mound was being eroded by bottom currents. Such erosion would create a turbidity layer with an oxygen demand just above the bottom, causing the decreased concentrations observed. The post-disposal survey showed that the dissolved oxygen levels immediately above the dump sites were not significantly different from D.O. concentrations in areas where dredged material was not dumped.

From an overall point of view, disposal of GBEC and TCCCB sediments did not have a significant adverse effect on D.O. concentrations in the disposal site water column during and immediately after dumping. Further, there were no observed long-term effects on the D.O. concentrations in the disposal area.

#### Heavy Metals

Heavy metals often receive the greatest attention in dredged material disposal operations because of their potential environmental impact. Some heavy metals can be highly toxic to aquatic life at low concentrations. However, as with other toxicants, it is important to consider the

available concentration and exposure times. The aqueous environmental chemistry of many heavy metals is such that with few exceptions, the predominant forms present in natural waters are non-toxic. This is especially true for dredged sediments where the association of the heavy metal with sediment would generally be expected to greatly reduce and possibly eliminate toxicity to most aquatic species.

Lee et al.<sup>3</sup> found that the only heavy metal expected to be released in the disposal site water column in sufficient concentrations to be potentially adverse to water quality is manganese. Elutriate tests on a wide variety of sediments from across the U. S. showed that nickel, copper, cadmium, mercury, chromium and lead would not be released in potentially significant amounts in open-water disposal of dredged sediments. For many sediments, zinc was removed from the elutriate test water by sorption processes. In elutriate tests conducted on GBEC and TCCTB sediments, Lee et al.<sup>1</sup> found a pattern similar to that of sediments taken from around the U. S.: the only heavy metal released in potentially significant amounts was manganese.

There was a highly variable heavy metal content in the water column and sediments of the GBEC. Pre-dredging and pre-disposal water concentrations of all soluble metals studied (manganese, chromium, cadmium, nickel, lead, zinc, copper, iron, mercury and arsenic) were generally below levels considered potentially hazardous to marine life by the US EPA.<sup>11</sup> Metal concentrations were usually higher in waters closer to Galveston Bay than to the open Gulf of Mexico.

The prevailing conditions of the turbid plumes that arose from disposal would be approximated by the oxic

elutriate test, which predicts that manganese would be the only heavy metal released in potentially significant concentrations in the turbid plume.<sup>1</sup> The studies on the concentrations of heavy metals present in the turbid plume showed that there was a release of manganese. This was the only heavy metal released in amounts which exceeded the critical level for chronic exposure.

Seven of the nine disposal operations monitored showed manganese release. The magnitude of release varied between dumps and seemed to be independent of other parameters measured. Galveston Dump No. 5 showed possibly the most significant release as moderately elevated manganese concentrations persisted for at least 35 minutes after the disposal. The data from TCC Dump No. 1 showed that the elevated manganese levels persisted only four minutes at the sampling site. When one considers the expected length of time an organism could be in contact with concentrations of manganese above the safe chronic exposure level recommended by the US EPA,<sup>11</sup> it seems likely that the release of this metal and others will not have a detrimental effect on water quality. As described above, this conclusion is based on the expected rapid dilution of the turbid plume that occurs and the intermittent nature of the dumping operation.

Iron, lead and nickel were also released in at least one dump. In Galveston Dump No. 4 at depths below 7 m, apparently soluble iron increased to a level of 227  $\mu\text{g/l}$ . The NAS-NAE considers 300  $\mu\text{g/l}$  of iron a hazard to the marine environment for chronic exposure.<sup>33</sup> In Galveston Dump No. 3, the 18-m samples showed soluble lead levels of  $\sim 39 \mu\text{g/l}$  (from  $\sim 9 \mu\text{g/l}$ ). Also slight nickel release was noticed in two of the nine disposal operations.

However, the magnitude of the apparent release and the duration of persistence of elevated concentrations of heavy metals because of the dumping operation would not be expected to cause any water-quality degradation.

Sediments analyzed in this study exhibited a wide range of total metal concentrations with no apparent trends between locations. Texas City Channel Turning Basin sediment did show higher levels of some metals, particularly copper, chromium and zinc, than did GBEC sediments. The metals most commonly found in highest concentrations in all sediments were manganese and iron.

The heavy metal composition of disposal site sediments was in general comparable to that of dredging site sediments. Manganese, iron and chromium concentrations generally were lower in the disposal area. Examination of the heavy metal data from GBEC Disposal Site sediments revealed considerable variation within the area. At least one sample each from the disposal and dredging sites was found to exceed the US EPA Region VI bulk sediment criteria of 75 mg/kg dry weight of zinc.<sup>16</sup> Texas City Channel Turning Basin sediment exceeded the criteria for arsenic and chromium. According to the US EPA criteria, these sediments are "polluted." Despite their elevated concentrations, these contaminants were not released to the disposal site water column during disposal of the TCCTB sediments. These results further emphasize the lack of technical validity in using bulk chemical criteria to estimate the potential environmental impact of dredged material disposal on the disposal site water column.

To reliably detect changes in sediment heavy metal concentrations arising from dredged material disposal, a much more extensive sediment sampling program than was possible in this study is required. Nevertheless, it is possible to conclude that disposal operations created no major changes in the heavy metal content of disposal area sediments as a result of the fact that the heavy metal content of the sediments in the disposal areas are of approximately the same concentrations--before and after disposal. From an overall point of view, the heavy metals in dredged material from GBEC and TCCTB sediments did not exert a significant adverse effect on water quality at the disposal site.

#### Nitrogen Compounds

Nitrogen compounds such as organic nitrogen, ammonium, nitrate and nitrite are of concern in dredged material disposal operations since certain concentrations of some of these compounds are highly toxic to aquatic life. Moreover, in nitrogen-limited waters, they can act as stimulants for the growth of aquatic plants. Generally, the importance of organic nitrogen compounds is not directly related to their concentrations, but to their ability to convert to ammonium, nitrite and nitrate under certain environmental conditions. The US EPA and its predecessor organizations earlier proposed dredged material disposal criteria based on the Kjeldahl nitrogen content of sediments.<sup>2</sup> Kjeldahl nitrogen is the sum of organic nitrogen and ammonium. Lee and Plumb<sup>2</sup> concluded that there is little or no technical validity for using the bulk Kjeldahl nitrogen content of the sediments as a basis for determining whether a sediment may be dumped in open waters.

The primary concern over nitrogen compounds in dredged sediments should be focused on the amount of ammonia released to the water column during disposal. Of chemical contaminants present in dredged sediment, ammonia represents the greatest potential hazard to aquatic life, both with open-water disposal and confined or onland disposal with overflow to a nearby watercourse.<sup>3</sup> The potential problems associated with ammonia are best judged by the release in the elutriate test. Elutriate tests of the same sediments used in this study showed the possibility of release of potentially significant amounts of ammonia to the water column during disposal operations.<sup>1</sup> The concentrations found could be harmful to aquatic life, but only if they remained undiluted for long periods of time.

Elutriate test results for sediments studied predicted that disposal of TCCTB sediments would release the greatest concentrations of ammonium. Very little ammonium release was predicted for GBEC sediments, with the greatest release expected from sediments dredged near GBEC Buoy 1. The expected patterns were found during actual disposal operations. Sediments dredged in the mid-to-upper reaches of the GBEC generally released little or no ammonium to the disposal site water column. Texas City Dump No. 2 showed ammonium release significantly higher than that associated with other disposal operations monitored. The highest concentration, 1.86 mg N/l, was in the bottom waters and persisted for less than two minutes while the turbid plume passed the anchored sampling ship. Measurable amounts of ammonium were detected in turbid plumes from other disposal operations, but they were lower than those found with Texas City Dump No. 2. However, elevated ammonium concentrations

persisted at any one point for only very short periods of time, usually in the order of a few minutes.

Even the highest ammonium concentrations found would not be toxic to aquatic life in the water column since under the temperature, pH and salinity conditions found in the water, several mg/l of ammonium nitrogen could persist several days and still not be toxic to most aquatic life.<sup>11</sup> The expected rate of dilution of the turbid plume, coupled with the intermittent nature of the dumping operation, is such that it would be unlikely that aquatic life would receive excessive exposure of ammonia in the GBEC Disposal Site water column. Data for post-disposal samples showed that ammonium returned to ambient levels within one day after cessation of disposal. Water samples collected one month after termination of disposal also indicated no increase in ammonium concentrations.

Increased concentrations of organic N were found in the turbid plumes. This is to be expected since organic nitrogen in natural water systems occurs primarily in a particulate form. No water-quality significance can be attached to a certain concentration of organic nitrogen in natural waters. It is very unlikely that organic nitrogen associated with the turbid plume would cause any water-quality problems as a result of conversion to ammonia. Under the conditions that prevail in the study area, the conversion of organic nitrogen to ammonia would be expected to be gradual, requiring from weeks to months. It is likely that any ammonia so formed would be dispersed in Gulf waters to the extent that its concentrations would not be of adverse significance to aquatic life. Further, in this type of water, the ammonium would not be stable but would convert to nitrate at a rate comparable to that of its formation.

Nitrate is not normally present in reduced environments. Under the reducing conditions that prevail in the TCCTB and the GBEC sediments, any nitrate present in the waters should be rapidly denitrified when in contact with the sediments, forming nitrogen gas and possibly other gaseous oxides of nitrogen. In several disposal operations nitrate content appeared to increase during passage of the turbid plume. However, there might have been some positive interference in the nitrate analyses due to iron and manganese and other materials. Assuming the detected nitrate increases were real increases rather than the result of some analytical error, their magnitude and duration should not have any adverse effect on water quality in disposal site waters.

#### Phosphorus Compounds

Phosphorus is of concern in dredged material disposal primarily because in phosphorus-limited waters certain forms of this element can stimulate the growth of aquatic plants. The seagrasses and benthic algae of the Gulf of Mexico serve as valuable food sources and habitats for fishes and invertebrates. However, massive amounts of algae occur seasonally at shallow depths in the Gulf, sometimes drifting ashore in quantities that are regarded as a nuisance.<sup>22</sup>

Pre-disposal studies indicated that total phosphorus and soluble orthophosphate concentrations in GBEC water were quite variable at all depths sampled. Soluble ortho P ranged from <0.02 mg P/l (detection limit) to 0.016 mg P/l; total P ranged from <0.02 mg P/l (detection limit) to 0.28 mg P/l.

This variability seemed to be related in part to tidal patterns. Rising tides bring in Gulf waters which are typically more saline and according to studies of El Sayed et al.,<sup>22</sup> lower in phosphorus than GBEC waters. The concentrations of soluble ortho P in GBEC waters generally decreased with decreased distance from open Gulf waters. This apparent pattern may be the result of reduced tidal influence and additional dilution of water of higher phosphorus concentration. This may indicate that the natural variability found farther seaward (Buoy D) would be less than that found at Buoy B. However, not enough samples were collected to show this conclusively.

Both total phosphorus and soluble orthophosphate concentrations were generally lower throughout the disposal area than in the GBEC. Concentrations in the water in G.S. 2 did not vary greatly during the three-month sampling period.

The total phosphorus content of GBEC sediments varied from 104 to 247 µg/l (dry weight) with no apparent pattern through the channel. These concentrations were fairly low compared to pre-disposal levels found in the disposal areas (60 to 699 mg P/kg). Again, there was no apparent pattern in phosphorus distribution. The total phosphorus content of the Texas City Channel sediments ranged from 473 to 1468 mg/kg (dry weight), which is at and above the upper range found in the disposal area prior to disposal. All of these sediment samples contained higher phosphorus concentrations than those found in GBEC sediment samples.

For TCCTB and GBEC samples, interstitial water soluble orthophosphate concentrations were greater than the highest concentrations found in the water column. This would indicate that there is a flux of soluble ortho P from

the sediments to the overlying water. No relationships were evident, however, between the soluble ortho P in the interstitial water and either soluble ortho P in the overlying water or total P in the surrounding sediment. It is possible that even though the concentrations in interstitial water compared to the concentrations found in the water column are very high, the sediments contribute very little to the overlying waters because mass transfer is small. The primary factor governing mass transfer from sediments is mixing associated with physical and biological processes. Substantial phosphate transfer could occur under conditions of intense storm activity. However, this phosphate would probably be of little consequence to the water column during these periods because rapid dilution would minimize the impact of this transfer. In addition, most coastal marine areas are nitrogen limited.<sup>47</sup> Replicate sediment grabs taken at Buoy D on August 25 showed that soluble ortho P concentrations in the interstitial water varied from 0.08 to 0.54 mg P/l. Interstitial water concentrations were more than quadrupled after disposal at Buoy D. However, IW concentrations in both Reference Grid Squares 15 and 27 showed 7.5-fold and two-fold increases after disposal, respectively. It has been found that the composition of interstitial water is highly variable and can change significantly as the result of a single storm.<sup>48</sup>

Data from nine disposal operations indicated that the direction and degree of change in soluble orthophosphate concentrations during disposal were unrelated to either the disposal site or the GBEC dredging site in question. The general trend was for soluble ortho P concentrations to increase (often coincident with decreased percent light transmission) and then to return rapidly to ambient levels.

Where these increases occurred, they ranged from 2- to 55-fold and appeared to be quite localized. Frequently, however, no increase was found in the surface waters. It did appear that TCCTB sediments, which were more contaminated than GBEC sediments, released less phosphorus than did the GBEC sediments. In some cases the former appeared to remove soluble ortho P from the water column by sorption and/or precipitation. This may have been related to the higher ambient soluble ortho P levels present at the disposal site prior to disposal of TCCTB sediments. Further, it would be expected that since the TCCTB sediments are in a more reduced condition than the GBEC sediments, the removal of phosphate by ferric hydroxide formed during dumping (oxidation of ferrous to ferric by D.O.) would be a more efficient scavenger for phosphate.<sup>49</sup>

The ambient soluble orthophosphate concentrations found near Buoy B appeared to increase with each successive disposal operation monitored. During the three-month pre-disposal study, soluble ortho P concentrations in Grid Square 2 generally varied between < 0.02 mg P/l (detection limit) and 0.032 mg P/l. In August, ambient concentrations ranged from 0.01 mg P/l to 0.05 mg P/l near Buoy B. During Texas City Dump No. 2, ambient levels in the disposal site appear to have been seven to ten times greater than they had been in August. These elevated levels were probably caused by natural variation in soluble ortho P concentration in the area.

A possible trend with respect to recovery time was seen in Galveston Dump Nos. 3, 4 and 5. The return to ambient concentrations of soluble orthophosphate at mid-depth occurred three minutes after Galveston Dump No. 3; the return after Galveston Dump No. 4 occurred in 6 to 8 minutes;

following Galveston Dump No. 5, it occurred within 10 minutes of disposal. The minor variations in recovery time may have been a function of the sampling sequence.

It is difficult to assess the effect of the disposal operations on water column soluble orthophosphate concentrations one month after dredged material disposal had ceased. Soluble ortho P concentrations in the disposal area had not fluctuated greatly during the April through June sampling, but this was not true for the entire year. Concentrations in November disposal site samples were generally 2.5 to 22 times greater than they had been either before or after the disposal operations. Since these increases were found both near actual disposal sites and in the grid squares where no disposal had occurred, the increases probably reflect normal concentration variations.

Changes in soluble orthophosphate concentrations resulting from dredged material disposal probably have little ecological significance for several reasons. First, it has been shown by Ryther and Dunstan<sup>47</sup> and Copeland and Fruh<sup>19</sup> that nitrogen limits algal growth in the coastal marine environment and in Galveston Bay waters. Copeland and Fruh<sup>19</sup> further stated that growth of aquatic plants in Galveston Bay is most likely limited by toxicants rather than by lack of nutrients.

As seen in the pre-disposal data, soluble ortho P concentrations were generally 0.01 mg P/l or higher, whereas inorganic N ( $\text{NH}_3\text{-N} + \text{NO}_3^-$ -N) concentrations were usually well below 0.3 mg N/l. The concentrations (0.01 mg P/l and 0.3 mg N/l) are usually regarded as the critical limiting factor in controlling algal growth.<sup>19,50</sup> In addition, the ratios (available N:available P) were generally less than 10:1 (atomic ratio), indicating that nitrogen would likely become limiting before phosphorus. Nitrogen concentrations

in May 7 samples rose above the 0.3 mg N/l level, while soluble ortho P concentrations remained in the same range found on other sampling dates. In most of these cases, the N:P ratio was still below 10:1 (atomic ratio). Several samples collected at the disposal site (April 17) showed N:P ratios as great as 39:1 (atomic ratio), indicating the possibility of phosphorus limitation before nitrogen limitation if other conditions favored algal growth.

During only three of the nine disposal operations monitored was there a pronounced increase-decrease trend in soluble orthophosphate with the passage of the turbid plume in the surface water. The ambient Secchi depth measured was generally about 2.5 m. According to Vollenweider,<sup>51</sup> an estimation of the depth of the photic zone can be made by multiplying the Secchi depth by a factor of between 1.5 and 3. If this factor is applied, the zone of photosynthetic algal growth should be restricted to the upper 7.5 m. Most of the phosphorus increase took place below this depth. The increased soluble ortho P at lower levels eventually would be circulated to the surface in diluted concentrations. The changes in concentration after dredged material disposal were short lived, as the soluble ortho P decreased to ambient levels within about one hour after the dump.

There has been some concern that the removal of nutrients from the water column could lead to lower productivity in areas which provide nursery grounds and food for fish and other aquatic life. The decreases resulting from dredged material disposal (namely Texas City Dump No. 2) were of such limited duration and extent as to have no effect on the productivity of these areas.

In order to evaluate the full significance of the soluble orthophosphate released during dredged material disposal in the GBEC and to determine the rates of dilution of elevated phosphorus concentrations, it is necessary to either make measurements as a function of time in the turbid plume or have a reliable dispersion model describing the fate of the turbid plume and any chemicals released during disposal operations. Insufficient funds were available to conduct studies on the fate of the turbid plume. At the time of preparation of this report a reliable dispersion model was not available. However, the phosphorus released during disposal operations at the GBEC disposal site would likely be of minor ecological significance because the phosphorus present is not likely to be limiting and because of the expected rapid dilution occurring in the nearshore waters of the Gulf of Mexico.

#### Carbon, Oil and Grease

As part of the investigation of the effects of dredged material disposal on water quality, organic content was measured in water and sediment samples collected from dredging and disposal sites at Galveston. Organic content was measured by two of the general parameters which are used as indices of organic contamination, namely, organic carbon and oil and grease. None of these tests measures strict chemical categories but each includes several organic compounds with varying physical and chemical properties. Total organic carbon (TOC) is a measure of the carbon content

of the organic material in the sample. Some unstable and highly volatile organics were not usually detected by this test. In the determination of oil and grease, a group of substances which dissolved in the chosen solvent is measured.

Water samples from five of the Galveston dumps and from Texas City Dump No. 2, collected before, during and after passage of the surface turbid plume, showed variable behavior with respect to total and soluble TOC and oil and grease. In Galveston Dump No. 1 soluble TOC decreased during and after the passage of the turbid plume. In Galveston Dump Nos. 2 and 3 and Texas City Dump No. 2 there was no significant change (at the 95 percent confidence level) in the soluble TOC concentration, before, during or after passage of the turbid plume. In Galveston Dump Nos. 4 and 5 soluble TOC tended to increase during the passage of the turbid plume and then decreased to ambient level after plume passage.

Data on oil and grease in the same samples showed that oil and grease concentrations ranged from <0.5 to 7.5 mg/l. It was observed that no measurable concentration of oil and grease was present in the samples collected before, during and after plume passage for the Galveston dumps. However, measurable concentrations of oil and grease were present in samples collected before, during and after plume passage for the Texas City dump. Statistical analysis of the latter data indicated that changes in the oil and grease during the passage of the turbid plume were insignificant at the 95 percent confidence level.

Dredging site sediments from the GBEC had variable concentrations of TC, TOC and oil and grease. Percent TC and percent TOC ranged from 1.1 to 5.5 and 0.3 to 0.9, respectively.

Oil and grease concentrations ranged from 18 to 437 mg/kg. Texas City Channel sediments had TC ranging from 0.9 to 1.9 percent and TOC ranging from 0.8 to 1.0 percent. The oil and grease concentration ranged from 255 to 1335 mg/kg.

Pre-disposal data on TC, TOC and oil and grease in disposal site sediments represented baseline characteristics of the sediments. Though data were collected over a period of six months, statistical analyses have shown no significant changes in the sediment characteristics during this period.

#### Summary of the Chlorinated Hydrocarbon Pesticides and PCB's Study

As part of the study of the environmental impact of dredged material disposal at the Galveston site, the behavior of fourteen chlorinated hydrocarbon pesticides and PCB's was investigated. Samples representing field conditions in the dredging and disposal sites were collected during the study period. A number of elutriate tests were run using selected sediments and waters from the GBEC and Texas City Channel. Also, a number of biological samples were collected from the disposal site i.. late November, 1975. Chlorinated hydrocarbon pesticides were determined by EC-GC on two columns of different polarity, and total PCB's were determined by chemical derivatization and EC-GC. The detailed results and discussion of this investigation are included in another report by Lee *et al.*<sup>1</sup>. The following section presents a summary of the results.

The study presented qualitative and quantitative characterization of the refractory organic residues in sediment, water and biological samples collected from the Galveston dredging and dredged material disposal area.

EC chromatograms of sediments from different sites showed permanent characteristic fingerprints consisting of 22 to 30 peaks with relative retention times (Rr) ranging from 0.36 to 7.3. The magnitude of the peaks showed wide variation from one site to the other, although the number of peaks was essentially the same. EC chromatograms of the water showed the presence of 12 to 16 peaks, all of which were of the same Rr values as those detected in the sediment. The profile of the organic residues in water samples showed slight variations from one site to the other. Four samples were collected before and during two dump operations of dredged material from the Galveston Bay Entrance Channel and the Texas City Channel. EC chromatograms before and during the dump were comparable and indicated no release of these pesticide residues. Only three of the biological samples were analyzed for chlorinated hydrocarbon pesticides and PCB's. These included a single spot fish, Leiostomus xanthurus of 15.2 cm total length, three small fish (unidentified species but considered as predators) of 2.5, 3.6 and 7.6 cm total lengths, respectively, and two white shrimp tentatively identified as Penaeus setiferous of 5.1 and 7.6 cm total lengths, respectively. The spot fish weighed 57.3 g, the three small fish all weighed 9.3 g and the two white shrimp weighed 23.9 g (without the exoskeleton). Single analysis was performed on each of the spot fish, the composite of the three small fish and the composite of the two white shrimp. The EC residue profile of these samples showed the presence of 16 to 22 characteristic peaks, 10 to 14 of which were of the same Rr as those detected in the sediment and water from the area.

Provisional identification of chlorinated hydrocarbon pesticides was based on two-column detection and

matching the R<sub>r</sub> values with those of standards. Lindane, aldrin, dieldrin, DDT and its analogs, 2,4-D esters, 2,4, 5-T and mirex were detected in almost all the sediment, water and elutriate samples. Quantitative values were determined for lindane, aldrin, dieldrin and DDT and its analogs. The PCB's were detected in all the samples at a wide range of concentration levels. The method of determination of total PCB's by chemical derivatization also offers confirmation as to the type of compounds present. Table VI-2 shows the concentration ranges of the selected chlorinated hydrocarbon pesticides and total PCB's detected in sediment samples collected throughout the study period from the GBEC, the Texas City Channel and the disposal sites. Table VI-3 shows the location and dates of sampling for these areas. Table VI-2 shows that Texas City sediments contain wider concentration ranges than the other sediments. Some of the Texas City Channel sediments were highly contaminated with chlorinated hydrocarbon pesticide residues and PCB's, indicating the potential for nearby point source discharge.

Table VI-4 shows the concentration ranges detected in water samples collected from the same sites as the sediment samples. The table also shows the lower detection limits (LDL) for the detected compounds and the US EPA Quality Criteria for Water.<sup>11</sup> It is noted that the concentration ranges within each site are comparable, except in the water phase of the hopper dredge where the upper level of total PCB's was relatively high (266 ng/l). It is also noted that in most cases the concentration levels detected in the water exceed the US EPA criteria. Total PCB's is the most obvious example where the criterion is only 1 ng/l while the concentrations detected ranged from 44 to 266 ng/l. For

Table VI-2  
 Concentration Ranges of Selected Chlorinated Hydrocarbon Pesticides and PCB's  
 in Sediments from Galveston Bay Entrance Channel  
Dredging and Disposal Sites

Sampling Location	Lindane	Aldrin	Dieldrin	DDT and Its Analogs	Total PCB's
Galveston Bay Entrance Channel	0.4-8.1	0.9-12.4	< 0.8	< 2.2-2.9	33-267
Texas City Channel	0.4-1.8	1.4-5.1	1.2-4.5	< 2.2-13.9	27-7426
Disposal Site "Selected Buoys"	0.6-1.5	1.2-1.8	< 0.8-0.9	< 2.2-3.4	155-437
Galveston Bay Entrance Channel Hopper Dredge Sediment Phase	0.7-1.3	0.6-1.4	< 0.8-1.3	< 2.2-2.4	47-307
Lower Detection Limits	0.2	0.4	0.8	2.2	6.0

See Table VI-3 for sampling locations and dates.

Table VI-3  
Sites and Dates of Sampling of Water and Sediment Collected from  
Galveston Area for Chlorinated Hydrocarbon Pesticides  
and PCB's Analyses

Sampling Location	Exact Site	Date	Total No. of Samples
Galveston Bay Entrance Channel (sediment and water)	Buoy 1	April 17, 1975	
	Buoy 9	April 12, 1975	
	Buoy 11	April 12, 1975	
	Between Buoys 1 and 4	August 26, 1975	4
Texas City Channel (sediment and water)	Site 1	March 28, 1975	
	Site 2	March 28, 1975	
	Site 3	March 28, 1975	
	Site 4	September 20, 1975	6
	Site 5	September 20, 1975	
	Site 6	September 20, 1975	
Disposal Site	Grid 11	April 17, 1975	
	Grid 15	April 17, 1975	
	Grid 28	April 17, 1975	
	Grid 8	April 17, 1975	3 (sediments)
			1 (water)
GBEC Hopper Dredge (sediment and water phases)	Between Buoys 1 and 3	August 26, 1975	
	Between Buoys 4 and 8	August 26, 1975	5
	Between Buoys 9 and 11	August 26, 1975	

**Table VI-4**  
**Concentration Ranges of Selected Chlorinated Hydrocarbon Pesticides and PCB's**  
**in Water from Galveston Dredging and Disposal Sites**  
(ng/l)

Sampling Location	Lindane	Aldrin	Dieldrin	DDT and Its Analogs	Total PCB's
Galveston Bay Entrance Channel	2.1-3.4	4.1-11.0	< 1.2	< 3.0-6.0	120-171
Texas City Channel	< 0.3-5.6	1.4-9.9	< 1.2	< 3.0	65-170
Disposal Site "Selected Buoys"	4.4	13.8	< 1.2	< 3.0	130
Galveston Bay Entrance Channel Hopper Dredge Water Phase	0.7-1.8	1.5-1.8	2.6-2.8	8.3-11.0	44-266
Lower Detection Limits	0.3	0.6	1.2	3.0	6.0
US EPA 1976 Criteria*	4	3	3	1	1

See Table VI-3 for sampling locations and dates.  
\*US EPA Quality Criteria for Water.

some of the compounds such as DDT and PCB's, the lower detection limits of the analytical methodology are higher than the established criteria. This is a problem that is frequently encountered in applying the recent criteria. For several chlorinated hydrocarbon pesticides, there is a lack of practical analytical methodology that detects with sufficient certainty and accuracy the compound at the specified criteria level.

Table VI- 5 shows the concentrations of chlorinated hydrocarbon pesticides and PCB's detected in the elutriate waters which were centrifuged from tests run at 5 and 20 percent sediment under oxic conditions. Results of the elutriate tests with 5 percent sediment showed variable tendencies of release and sorption. These tendencies were related to the oil and grease and iron content of the sediment. Elutriate tests run with 20 percent sediment generally showed tendencies for release, the extent of which was also related to the sediment characteristics.

Table VI-6 shows the concentrations of selected chlorinated hydrocarbon pesticides and PCB's detected in spot fish, small fish and white shrimp collected from the GBEC disposal area. The table also includes the LDL and the 1976 FDA guidelines for fish and shellfish.<sup>52</sup> The concentrations in these samples are well below the guidelines for edible fish and shellfish.

The study indicated no potential release of chlorinated hydrocarbon pesticides and PCB's during the dredging and disposal operations at the Galveston site. No detectable change in the concentrations of chlorinated hydrocarbon pesticides and PCB's was observed in samples collected before and during the dump operations. Based on the data obtained thus far, the concentration levels of chlorinated

Table VI - 5  
 Concentrations of Chlorinated Hydrocarbon Pesticides and PCB's in  
Elutriate Water from Tests Run on Samples from the Galveston  
Bay Entrance Channel and Texas City Channel

Sampling Location	Lindane	Aldrin	Dieldrin	DDT and Its Analogs	Total PCB's
<u>GBEC</u>					
5 percentoxic (Buoy 1)	2.5	2.8	< 1.2	5.2	170
20 percentoxic (Between Buoys 1 and 4)	14.3	35.1	< 1.2	3	261
<u>TCC</u>					
5 percentoxic (TCC 1)	1.5	3.6	< 1.2	3	150
20 percentoxic (TCC 4)	1.6	8.9	< 1.2	20.6	9620

Table VI- 6  
 Concentrations of Selected Chlorinated Hydrocarbon Pesticides and PCB's  
 in Biological Samples Collected from the  
GBEC Disposal Site

Concentration ( $\mu\text{g}/\text{kg}$ )	Spot** ( $\mu\text{g}/\text{kg}$ )	Small Fish** (Composite of 3)	White Shrimp + (Composite of 2)	Lower Detection Limits*	US FDA Guideline Levels* (for edible portion)
Lindane	0.2	0.4	<0.2	0.2	NL
Aldrin	1.3	1.1	<0.4	0.4	300
Dieldrin	<0.8	<0.8	<0.8	0.8	
DDT and Its Analogs	4.6	4.9	<2.0	2.0	5000
Total PCB's	95.1	35.1	6.3	6.0	5000

\*US FDA.<sup>52</sup>

\*\*Analysis was run on whole or composite of whole organism.

+ Analysis was run on composite of two organisms without the exoskeleton.  
 NL = no limits.

hydrocarbon pesticides and total PCB's in fish and white shrimp taken from the disposal area were well below the FDA guideline levels.

Comparison of Results to Dredged Material  
Disposal Regulations

One of the major tasks facing EPA and the U. S. Army Corps of Engineers with respect to dredging is the development of guidelines for the evaluation of proposed discharge of dredged or fill material into navigable waters. The requirement for the guidelines comes from Section 404 (b) of PL 92-500, and the guidelines are presented in the "Federal Register", Volume 40, No. 173, September 5, 1975, in Sections 230.4 and 230.5.<sup>53</sup>

According to these guidelines, a mixing zone is to be estimated for each disposal site, and the interim guidance for calculating the mixing zone will be supplied by the District Engineer. Elutriate concentrations, ambient concentrations in the disposal site water and other information about the material to be dumped and about the disposal site are to be used in the estimation of the mixing zone. This interim guidance has been set out in Miscellaneous Paper D-76-17 of the Dredged Materials Research Program by the Environmental Effects Laboratory of the U. S. Army Engineer Waterways Experiment Station in Vicksburg, Mississippi.<sup>54</sup>

An attempt has been made to consider the method of mixing zone estimation outlined in D-76-17 in the light of field and laboratory data obtained in this study and a companion study.<sup>1</sup> It was found that the description of the method for estimating the mixing zone in D-76-17 was unclear and somewhat nebulous. There are a number of instances when the approach used by the Corps of Engineers, WES, in D-76-17 did not appear to be applicable in the GBEC Disposal Site and possibly to other similar disposal operations. Some of

the most important areas that need clarification are the settling velocities and appropriate criteria to be used to judge critical concentrations of contaminants at the edge of the mixing zone. In general, the appropriate criteria that should be applied at the edge of the mixing zone are unknown. Some of the terms used in D-76-17 in describing the mixing zone also need further clarification.

As discussed in an earlier section, the criterion used for any particular parameter must exceed the critical concentration-time of exposure relationship for an organism of concern that inhabits the disposal area water column. Concentrations considerably greater than the US EPA Quality Criteria for Water (chronic exposure criteria) can be allowed for short periods of time without having a significant adverse effect on water quality at the disposal site.

The potential importance of the time of exposure-concentration relationship is demonstrated in a recent paper by Mattice and Zittel concerned with the impact of chlorine on aquatic organisms.<sup>55</sup> Based on a literature review of studies on the toxicity of chlorine to aquatic organisms as a function of time of exposure, Mattice and Zittel determined that for marine organisms of all types tested, the acute safe level of chlorine for a one-minute exposure was approximately 0.15 mg/l. For 10 minutes of exposure the safe level for acute toxicity was approximately 0.06 mg/l while for 100 minutes of exposure the safe level for acute toxicity was 0.03 mg/l chlorine. They also reported that a chronic safe level for chlorine was in the order of 0.02 mg/l. Various investigators have found as reported by Mattice and Zittel<sup>55</sup> that many organisms can be exposed to much higher levels of chlorine without significant adverse effects provided that the time is kept short.

The importance of these results is that for acute toxicity, a doubling of the safe acute toxicity level is achieved when the exposure time is reduced from 100 minutes to 10 minutes. For freshwater systems Mattice and Zittel have found a much steeper slope for the relationship between the acute toxicity threshold for chlorine and the duration of the exposure.<sup>55</sup> Decreasing the duration of exposure from 100 minutes to 10 minutes increases the acute toxicity threshold from approximately 0.04 mg/l to 0.2 mg/l chlorine. Unfortunately, there are very limited amounts of data of the type needed to judge the critical time-concentration relationship for aquatic organisms' exposure to contaminants normally associated with dredged material disposal for the times that are of potential concern in dumping operations.

The attempts of this report to apply the mixing zone estimations outlined in D-76-17 and in the modified Koh-Chang dispersion model to these field studies have led to the following conclusions. It is apparent that neither model adequately considers the fate of both the mass of discharged material and of the turbid cloud which separated from it at the initial release. These two volumes of material behave differently at the site, have different ecological impacts and both should be considered. For most constituents studied here, calculated mixing zone volumes required for adequate dilution cannot be used in calculations in D-76-17 to estimate the physical size of the mixing zone.

In accord with D-76-17, in order to determine whether the computed mixing zone is excessive, a case-by-case evaluation must be made of the physical, chemical and biological characteristics of the disposal site water column. In situations such as the GBEC disposal area, it

is reasonable to expect that a much larger release of contaminants would be allowed than for areas where there may be restricted mixing, unique biological habitats and limited total volume available for mixing, etc.

#### Bioassay Results

In the previous sections of this report the conclusion that the contaminants present in the dredged sediment would not have a significant adverse effect on water and sediment quality at the GBEC disposal area is based on consideration of the amounts of contaminants found during actual disposal operations in the water column and in the sediments after disposal. The intermittent nature and short duration of the disposal operations would virtually preclude any significant adverse effects (toxicity) on water column organisms.

Support for the lack of toxicity of the disposal of dredged sediments at the GBEC disposal area is provided by the bioassay studies of Lee *et al.*<sup>1</sup>. In these studies the elutriates of sediments from the GBEC and the Texas City Channels were tested for toxicity to P. pugio (grass shrimp) in a 96-hour bioassay. The tests generally employed a 5, 10 and 20 percent sediment of the total elutriate volume. This is a volume by volume percentage basis. The 20 percent sediment is estimated to be roughly equivalent to the concentrations of contaminants that would be released in the dredge pump discharge.

The bioassays were conducted in such a way as to leave the sediments in contact with the grass shrimp for the 96-hour test period. A summary of the data obtained in these bioassays is presented in Table VI-7 . Examination of this table shows that very little toxicity was demonstrated by the dredged sediments from either the

Table VI-7

Acute Toxicity of Galveston Bay Entrance Channel and Texas  
City Channel Sediments to *P. pugio*

Sediment Location	Percent Surviving at 96 Hours		
	Sediment Percentage		
	5	10	20
<b>GBEC</b>			
Bouy 1	90	100	85
Buoy 9	-	100	-
Buoy 11	100	100	90
<b>TCC</b>			
Site 1	100	100	100
Site 2	90	90	80
Site 3	90	90	80
Site 4	90	80	85
Site 5	100	100	100
Site 6	100	-	95

Dash (-) indicates no test made.

GBEC or the Texas City Channel. In fact, the most contaminated sediments based on bulk chemical criteria would be the Texas City Channel Site No. 1, yet this site showed no toxicity to grass shrimp over the 96-hour period. It was near Site 1, i.e., the Turning Basin, that the dredging took place for the Texas City Dump Nos. 1 and 2.

These bioassay results, while based on acute lethal tests, i.e., the standard 96-hour tests, do provide (through the use of an application factor) some indication of the potential chronic toxicity of these sediments to aquatic life. It has been found in a number of tests that

the relationship between the 96-hour acute lethal results and the chronic exposure (usually lifetime) safe level is a factor of 100. The bioassay tests were run in what was equivalent to the dredging pump discharge for a period of four days and showed no toxicity to grass shrimp for the case of Texas City Site No. 1 sediments. Thus, the likelihood of significant toxicity to water column organisms or for that matter to benthic organisms (since the grass shrimp were in contact with the contaminated sediments for this period) is remote. It is also interesting to note that the GBEC sediments which would be classified as relatively uncontaminated based on the US EPA bulk chemical criteria show the same toxicity levels to grass shrimp as the Texas City Channel sediments which would be classified as grossly contaminated based on the same criteria.

The chemical characteristics of the sediments dredged from the GBEC are quite similar to the chemical characteristics of the sediments present in the GBEC disposal area. The physical effects of grain size and the overall organic content of the sediments would probably not have an adverse effect on the numbers and types of organisms present near the disposal sites. Based on these considerations, it would be appropriate to conclude that the chemical contaminants present in the dredged sediments would not be likely to have any effect in determining the numbers and types of organisms present in the area. The bioassay studies demonstrated that even in a very concentrated sediment water system equivalent to that discharged by the dredge, the contaminants did not show any appreciable toxicity to grass shrimp. Further, upon disposal there would be substantial dilution of the dredged sediments with sediments of the region as a result of mixing processes arising from tidal and storm-derived currents.

These factors would make any significant adverse effect of chemical contaminants present in the sediments on the numbers and types of organisms present at the disposal area somewhat remote.

An area in which there were insufficient funds available to properly define the significance of chemical contaminants present in the sediments is bioconcentration of contaminants within aquatic organisms. This is an area that needs additional study before it may be concluded that the chemical contaminants present in the dredged sediments are not having a significant adverse effect on higher trophic levels and on the use of commercially available species for human food.

## PART VII: CONCLUSIONS AND RECOMMENDATIONS

### Conclusions

The following conclusions have been developed as a result of this study:

- a. Water quality at the Galveston Bay Entrance Channel Disposal Site is highly variable. Water quality at any time and place is partially a function of depth in the water column since the Galveston Bay waters tend to overlie the more dense, saline Gulf of Mexico waters. The primary determinant of water quality, however, is the mixture of uncontaminated Gulf of Mexico open waters with Galveston Bay waters, which tend to be more highly contaminated with chemical contaminants of potential concern, and with nearshore Gulf waters, which are generally less contaminated than Galveston Bay waters. The relative contributions of these three water sources is highly variable, being dependent primarily on the water currents, which are in turn influenced by tide and wind. This, coupled with the fact that during storms the full length of the water column can be mixed causing appreciable sediment suspension, leads to a highly variable water quality which is independent of any dredged material disposal.
- b. Dredged material disposal at the Galveston Bay Entrance Channel Disposal Site was found to have no significant effect on water quality in the disposal site water column. This was true whether the sediments were taken from the relatively uncontaminated Galveston Bay Entrance Channel or from the highly contaminated Texas City Channel and Turning Basin. Any changes in the water quality at the disposal site water column arising from dumping were of short duration at any one location, lasting from a few minutes to a few hours. Moreover, the elevated concentrations associated with any particular disposal operation were confined to a relatively small area.

- c. One of the areas of potential concern associated with chemical contaminants in dredged sediments is the bioconcentration of selected contaminants which cause the concentrations to build up in higher trophic level organisms to be adverse to the organisms and/or man's utilization of the organisms as a source of food. The chemicals of greatest concern are certain of the heavy metals such as mercury, cadmium, the chlorinated hydrocarbon pesticides and PCB's.
- d. While the studies that have been conducted contribute significantly to understanding the potential significance of chemical contaminants in dredged sediments during open-water disposal operations such as those conducted in the Galveston Bay Entrance Channel Disposal Site, insufficient funds were made available in this study to investigate to the degree necessary several important areas.

#### Recommendations

The following recommendations are made based on the results of this study:

- a. It is recommended that use of bulk chemical criteria as a basis for determining suitable locations for dredged material disposal be terminated. In lieu of these criteria, the approach outlined in the September 5, 1975 "Federal Register", which presents PL 92-500, Section 404, Guidelines for Dredge and Fill Material, and the guidelines for dredged material disposal being developed for the Ocean Dumping Act, PL 92-532, should be adopted. The elutriate test should be utilized to estimate the potential for release of chemical contaminants in dredged sediments to the disposal site water column. In addition, bioassay tests should be utilized to estimate the potential for significant bioaccumulation of chemical contaminants and significant adverse effects on benthic and epibenthic organisms.

- b. It is recommended that studies be conducted to determine whether organisms present in the sediments, upon the sediments and in the overlying water column in the dredged material disposal area have a significantly higher concentration of various chemical contaminants such as chlorinated hydrocarbon pesticides, PCB's and heavy metals than organisms taken from non-disposal areas from the same general region. If elevated concentrations are found, then studies should be initiated to determine whether the dredged material disposal operation is contributing to the elevated concentrations and what the significance of these elevated concentrations is on aquatic organisms and the utilization of these organisms for use as food by man.
  - c. It is recommended that further studies be done to define the ultimate fate of the suspended sediments as released to the water column during disposal operations. This may be done through verified mathematical models and/or field studies. The objectives of these studies would be to determine concentration-time relationships that exist for various forms of available chemicals present in the turbid discharge plume which could have an adverse effect on water quality and aquatic organisms at the disposal site.
  - d. Comprehensive studies should be initiated on the environmental impact of dredged material disposal in confined or on-land areas in the Texas Gulf Coast region. This would enable comparison of the environmental impact of open-water disposal such as studied in this investigation, with that of confined or on-land disposal where the water associated with the dredged sediments is allowed to return to the nearby watercourse. Particular attention should be given to studying dredging sites where confined or on-land

disposal has been adopted because it is considered more "ecologically sound" than the previously used and less expensive open-water disposal.

- e. The results of this investigation and future investigations on the environmental impact of confined or other alternate methods of dredged material disposal in the Texas Gulf Coast region should be utilized to develop a new dredged material disposal policy. Such a policy would minimize the overall environmental impact of dredged material disposal and reduce the cost of dredging to the minimum necessary to achieve desired environmental quality in the disposal site region.

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